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Mineral nutrition of developing soybean seedlings -- A greenhouse investigation with nutrient solutions and sand medium

by

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ABSTRACT

Although soybean seeds generally contain adequate amounts of most nutrients for early seedling growth and development, they are often low in certain nutrients. We hypothesize that such deficiencies adversely affect seed germination and early seedling development, and that supplying the deficient nutrients enhances germination and seedling development.

The major objectives of this study were to investigate: (1) the quantitative and qualitative relationships among various nutrient solutions and developing soybean seedlings; (2) the effects of these solutions on the accumulation or loss of dry weights and nutrients in roots, shoots, and cotyledons; (3) which nutrients were more crucial for the early development of soybean seedlings; and (4) the period during which these nutrients are needed most.

The study, conducted under greenhouse conditions, consisted of seven experiments. Each experiment was arranged in a replicated randomized block design. Soybeans were grown in acid-washed sand in plastic cups. Treatments included a factorial combination of Ca and Mn in deionized water, and factorial deletions of Ca and Mn from Hoagland Solution.

The seedlings were sampled at the pre-emergence, emergence, unifoliate and second trifoliate stages which occurred at 1, 7, 12, and 19 days after planting, respectively. Plants were partitioned into roots, shoots, and cotyledons; each portion was weighed and analyzed for P, K, Ca, Mg, Mn, B, Fe, Cu, Al, and Zn.

Dry weights of cotyledons decreased irrespective of treatment; conversely, increases in dry weights of roots and shoots varied due to Ca (primarily) and Mn treatments; other nutrients had little influence on seedling growth. If only Ca and Mn in water were supplied, root weight was larger than shoot weight; in Hoagland Solution, root and shoot weights were similar.

Depletion of most nutrients from the cotyledons occurred. However, the low Ca depletion, along with a decline in cotyledon dry weight, increased Ca concentration in the cotyledons. The contents of any one nutrient in roots and shoots were influenced by its presence or absence in solution and was modified by the presence of Ca and Mn. The shoots generally had higher nutrient contents than the roots. Differences in nutrient contents were related to differences in dry weights.

INTRODUCTION

While much has been written about plants, little is known about the nutrition of seedlings. This is partly because it has generally been assumed that seeds contain and do supply, in the right proportions, all the nutrients that a young seedling requires until it is capable to absorb nutrients from the soil or growth medium. The lack of publication in this area is also partly due to the difficulties involved in conducting a study of this nature. This lack of published material turned out to be one of the major problems encountered in our investigation. Notwithstanding this and numerous other difficulties encountered throughout the study, we were able to develop a plan of work that is of acceptance in scientific research of this nature; and one that is verifiable.

Although seeds generally contain most nutrient elements in large quantities, they are often low or deficient in certain nutrients. For instance, while soybean plants contain about 0.65 percent Ca at harvest, there is only about 0.18 percent Ca in the seeds (Borst and Thatcher, 1931). In cases like this, the likelihood of calcium deficiency occurring in young seedlings, whether apparent or not, is very high, especially when grown in soils low in calcium. The hypothesis of our study therefore was that seed germination and seedling development could be enhanced when the growth medium contained or supplied adequate amounts of nutrients that were deficient in the seeds. We used soybeans as a test crop because the seeds were found to contain significantly smaller amounts of Ca as compared to the plants. Hence, assuming that the developing seedlings would require as much calcium as was in the plants, it was safe to conclude that the seeds were deficient for adequately supplying the seedlings' calcium requirements.

The major objectives of this study were as follows: 1. To determine the quantitative and qualitative relationships between various nutrient solutions and developing soybean seedlings. 2. To determine the effects of these nutrient solutions on dry weights and the chemical composition of roots, shoots, and cotyledons of developing seedlings. How do these nutrient solutions influence the translocation and redistribution of dry matter and nutrients in these parts? 3. To determine which nutrient element(s) are more crucial for the early development of soybean seedlings. 4. To determine the period during which these nutrients are needed most.

Knowledge acquired through research of this nature is of broad practical significance and application to both researchers and to the farmers. To the researcher it is another area of challenge in the never ending struggle to understanding the mechanisms of plant growth and development. Because the hypothesis upon which this study is based contradicts conventional wisdom it might stimulate a controversy, the resolution of which, we hope, will enrich our knowledge of plant physiology in general, and seed physiology, in particular. The ultimate result of this research, we hope, will be the development of better and healthier seedlings which produce mother plants with potentials of higher yields in the forms of grain, forage, etc.

LITERATURE REVIEW

Most crop plants begin as seedlings which, through a combination of factors, processes, and conditions, eventually develop into plants. The role of the various mineral nutrients in plant growth is a well-researched subject. Studies into the mineral nutrition of plants, nutrient accumulation, transformation, and redistribution of nutrients in the plants have been conducted for several generations; and information on the nutrition of mature plants abounds in the literature. Therefore, owing to the fact that plants begin as seedlings, it would seem that comparable studies into the mineral nutrition of seedlings have been conducted. Unfortunately, this is not the case. A search of the literature revealed that very few studies have focused on the nutrition of seedlings. The few available publications on mineral nutrition of seedlings, in general, and leguminous plants, in particular, are reviewed in the following section. Because of the limitations of literature on this subject we are unable to restrict, as much as we would have liked, this review to the soybean, our choice as a test plant. Equally so, and for the same reason, this review is very limited in scope--a shortcoming over which we had no control. Much of the relevant work in this area dates back to the first half of this century.

Previous Studies

Dr. J. H. Kastle, Director of the Kentucky Experiment Station, conducted experiments to study the translocation of mineral nutrients in plants. He observed that the morning-glory vine (<u>Ipomoea purpurea</u>), after removal from the soil, would continue to grow when its roots were immersed in rain water. Often the growth continued up to seed production. As a result of these investigations, interest to determine the translocation of the mineral matter contained in the seeds developed. This led Buckner (1915), then a junior scientist under Dr. Kastle, to carry out experiments on the seeds of the garden bean (Phaseolus vulgaris), corn (Zea mays), and the potato tuber (Solanum tuberosum). In these studies, he confined his work to measuring the translocation of phosphorus, calcium, potassium, magnesium, and silicon.

Buckner (1915) grew his plants in a sand medium under aseptic, dust-proof conditions. The distilled water used was boiled for 20 minutes before coming in contact with the beans. He found the cotyledons of the garden beans to contain a considerable amount of mineral matter, and the seedlings were hardy and well-adapted for the experiments. The beans were germinated and allowed to grow at the expense of the food stored in the cotyledons. Although only distilled water was applied, the beans germinated and produced perfect seedlings; but gradually seedling development was hampered by the lack of food. He noted that the seedlings were sustained by food reserves of the cotyledons for about 17 to 22 days. He analyzed whole beans, as controls, and 17 to 22 day-old seedlings for their mineral components mentioned earlier. Individual mineral elements were expressed as the percentages they comprised of the total ash content found in the given parts.

Phosphorus

Buckner (1915) observed that the percentage of phosphorus in cotyledons of ungerminated whole garden bean seeds (expressed as P_2O_5) was 34.22; in cotyledons of 22 day-old seedlings, it was 35.18, a slight increase of nearly 1 percent. In the integuments removed from these two groups of cotyledons, he observed a decline of phosphorus in the seedlings (1.91 percent) as compared to 3.91 percent for the whole seed. The alcoholic drainage and washings were evaporated to dryness and saved for analysis. This was labeled "drain". His further observation that phosphorus in the drain was 9.16 and 18.12 percent for the whole seed and seedling, respectively, is interesting. Phosphorus lost from the seed was translocated to the roots, stems, and leaves. Buckner gives the percentage distribution of each element which actually migrated from the cotyledons to their final location in the different parts of the seedlings. He found that approximately 50 percent of the total mineral content of the cotyledons remained unused and that slightly over 50 percent was translocated to different parts of the seedlings. For phosphorus, he reported 47.20 percent remained in the cotyledons. In the roots, stems and leaves he found 7.68, 20,78, and 24,34 percent, respectively, of the phosphorus which originally was in the cotyledons.

These results with the garden beans were dissimilar to his later findings with the jack beans (Buckner, 1919). Here, Buckner reported about 70.9 percent of the phosphorus remained in the cotyledons, while only 2.6, 21.3, and 5.2 percent migrated to the roots, stems, and leaves, respectively.

von Ohlen (1931), working with soybeans grown in quartz sand, reported that during the first five days there was an increase in the amount of inorganically bound phosphorus in the hypocotyl and roots. The organically bound phosphorus decreased somewhat at the apex of the hypocotyl but remained about constant at the base of the hypocotyl and root. He reported further that a gradual decrease occurred in all mineral elements between the 11th and 29th days at the base of the epicotyl, and of the organically bound phosphorus of the apex. He found it impossible to test for organically bound phosphorus for the last few days. In the cotyledons, von Ohlen (1931) reported that there was a slight increase during the first 5 days in the amount of inorganically bound phosphorus, and a small decrease in the organically bound phosphorus. A negative test was obtained for organically bound phosphorus on the 25th day. The inorganically bound phosphorus gradually increased in the cotyledons during germination and was detected in fair amounts on the last day. In the plumule, von Ohlen observed that both forms of phosphorus remained about the same.

McAlister and Krober (1951), in the work most relevant to our study, studied dry weights and N, P, K, Ca, and Mg contents of the cotyledon of seedlings of two soybean varieties growing in sand in the greenhouse and in soil in the field. They reported that the maximum rate of transfer of phosphorus from the cotyledons to the seedling occurred from 2 days before emergence to 4 days after emergence. They found an average of 79 mg of phosphorus in ungerminated seeds; of this an average of nearly 73 mg of phosphorus was tranferred to the seedlings 28 days after emergence. As the seedlings emerged, about 38.50 percent of the P that migrated had been transferred from the cotyledons to the seedlings. They further reported that 4 days after emergence the rate of translocation of P began to diminish, and by 20 days after emergence only moderate to small transfers were observable. They found that, in total, nearly 79.50 percent of the mobil P was translocated from the cotyledons. McAlister and Krober did not analyze different parts of the seedlings to determine the distribution of phosphorus in those parts of the seedlings.

Potassium

Buckner (1915) analyzed whole beans and bean seedlings for potassium expressed as K_2O. He reported that 47.99 percent of the total ash in whole beans comprised of potassium. In the 17 to 22 day-old seedlings, about 42.40 percent of the total ash in the seedling comprised of potassium. Looking at the relative distribution of potassium in the various parts of the seedlings, he found that of the total K in the seedling 37.23 percent was in the cotyledon, 7.21 percent in the roots, 38.17 percent in the shoots, and the remaining 17.42 percent was accounted for in the drain and integuments. In his work with soybeans, von Ohlen (1931) reported an abundance of potassium in the seed and all parts of the seedlings at emergence. He observed that by the third day after emergence, potassium decreased slightly in all parts of the seedling except in the root apex where it remained in abundance. After the 5th day, potassium content of the base of the root and the hypocotyl remained about constant. Between the 11th and 29th days, there was a gradual decrease in K at the base of the epicotyl.

McAlister and Krober (1951), using soybeans as a test crop, reported a rapid loss of K from the cotyledons from planting until emergence and then a gradually decreasing rate of loss to the 40th day. They found an average of approximately 0.247 gm of K in 200 cotyledons before planting and about 0.070 gm remained 28 days after emergence. Of the K translocated to the seedling, between 44 to 62 percent had been translocated by the time of emergence and up to 80 to 90 percent six days thereafter. They did not determine the relative distribution of this nutrient in various parts of the seedling.

Calcium

In garden beans, nearly 55 percent of the calcium (as CaO) in the seed remained in the cotyledons at 22 days after emergence (Buckner, 1915). Buckner found calcium concentration in the cotyledons of the bean seedling at 22 days after emergence was twice as high (2.45 percent) as in the whole seed (1.30 percent). He reported calcium content in the ash of roots, stems, and leaves to be 13.72, 22.50, and 10.45 percent, respectively. These represent the percentage distribution of calcium in the various parts of the bean seedlings--calcium which actually migrated from the cotyledons. In his later work with jack beans, Buckner (1919) observed some striking differences. He found that only about 36.0 percent of calcium remained in the cotyledons of 22 day-old seedlings. He, however, found a very high level of calcium (49.6 percent) in the leaves. The percentage distribution of calcium that actually migrated from the cotyledons found in the roots and stems were 2.6 and 11.8, respectively.

McAlister and Krober (1951) studied the loss of calcium from the cotyledons of soybeans. For the two varieties in their investigation they observed that little, if any, transfer of calcium from the cotyledons to the seedlings occurred. To the contrary, they noted that as soon as emergence had occurred, the cotyledons apparently began absorbing calcium from the seedling. The calcium content of the cotyledons averaged 28 mg in ungerminated seeds, about 32.5 mg at emergence, and rose sharply thereafter, reaching an average 112 mg 28 days after emergence. This pattern differs from that reported by Buckner for garden beans and jack beans and also for the patterns reported for other nutrients discussed earlier.

Magnesium

McAlister and Krober (1951) found that only a very small quantity of magnesium was translocated from the cotyledons of both varieties of soybeans they tested. There was a gradual loss of magnesium during the first 3 days of the greenhouse germination period; from that time on there was virtually no change in Mg until after 25 days, at which time a sharp increase was observed. In their final samples taken at 40 days after planting, the Mg content in the cotyledons was nearly as high or higher than in the original samples from ungerminated seeds.

In earlier work on soybeans, von Ohlen (1931) reported that there was a slight increase during the first 5 days in the amount of inorganically bound magnesium, and a small decrease of the organically bound magnesium in the cotyledons. A negative test was obtained for organically bound magnesium on the 21st day. The inorganically bound magnesium gradually increased in the cotyledons during germination and gave a fair test on the last day. In the plumules, there was a slight decrease in both forms of magnesium. There was an increase in the amount of inorganically bound magnesium in the hypocotyl during the first five days. von Ohlen noted further that the organically bound magnesium decreased somewhat at the apex of the hypocotyl but remained constant at the base of the hypocotyl and root. After the 5th day, the mineral content of the base of the root and the hypocotyl remained about constant, except for the last few days when it was impossible to get tests for organically bound magnesium. Between the 11th and 29th days after emergence, a gradual decrease occurred in all mineral elements at the base of the epicotyl, and of the organically bound magnesium at the apex.

Buckner (1915) studied the translocation of the constituents of garden beans, corn, and potato tuber. He found that nearly 45.67 percent of the magnesium (as MgO) remained in the cotyledons of 22 day-old seedlings. Of the magnesium that migrated from the cotyledons, he reported that of the total amounts found in the various plant parts, 6.14 percent was in the roots, 18.28 percent in the stems, and 27.83 percent in the leaves. Comparative analyses of whole beans and seedlings revealed that magnesium in the ash was 3.51 and 3.26 percent, respectively.

In his work with garden beans, corn, and potato tuber, Buckner (1915) also studied the translocation of magnesium. He reported that nearly 45.6 percent of the magnesium (as MgO) in 22 day-old bean seedlings remained in the cotyledons. Of the magnesium that migrated from the cotyledons, he reported that of the total amounts found in the various plant parts 6.14 percent was in the roots, 18.28 percent was in the stems, and 27.83 percent was in the leaves. Comparative analyses of whole beans and bean seedlings revealed that magnesium in the ash was 3.51 and 3.26 percent of the dry weights of the whole beans and bean seedlings, respectively.

In his work with jack beans, Buckner (1919) observed a similar pattern in translocation and redistribution of magnesium as reported above for garden beans. In the ash of whole jack bean seeds and seedlings, he found 4.58 and 4.24 percent of the dry weights, respectively, to comprise of magnesium (expressed as MgO). The relative distribution of magnesium in various parts of the seedlings was as follows: 34.6 percent in cotyledons, 2.6 percent in roots, 31.0 percent in stems, and 31.7 percent in leaves.

<u>Mineral nutrition of corn seedling</u>

Buckner (1915) conducted similar experiments with corn, except here the seedlings were grown in aluminum cups instead of in paraffined containers. The seedlings were allowed to grow for 23 days, when they began to etiolate, at which time they were removed and dissected into four groups: leaves, cotyledons, stems, and roots. Each lot of material was analyzed in the same manner as the bean seedlings. In addition, the translocation and redistribution of iron and aluminum were studied. The sum of total ash of the various parts of the corn seedlings exceeded the total ash of the corn grain by 0.9487 gm or by about 14.67 percent. Buckner believed this increase was due to the fact that iron and aluminum were taken up in considerable amounts from the cups used and also by contamination with dust from the outside. He saw that the sum of the amounts of P, K, and Mg in the separate parts of the seedlings expressed as percentage of total dry weights agreed with that of the corresponding amounts of these nutrients in the corn grain. On the same basis, the amounts of Ca, Si, Fe, and Al found in the various parts of the seedlings were in excess of the amounts of these nutrients found in the corn grain. Buckner thought these increases were the result of contaminations as mentioned earlier.

The percentage distribution of the mineral constituents of corn seedling during growth of the seedling was somewhat different from that reported for the crops already mentioned. A comparison of the individual mineral elements showed that, except in the case of potassium and aluminum, approximately 50 percent of the minerals were translocated from the cotyledons to other parts of the seedling during growth. The translocation of potassium was 80.0 percent while that for aluminum was nearly 95 percent. There was a decided accumulation of translocated mineral matter in the leaves of the seedlings, except in the case of iron and aluminum. The distribution of translocated iron was almost evenly distributed between stems and roots. In the case of aluminum, over 88 percent was found in the roots, the rest being almost evenly distributed among leaves and stems. The high levels of Fe and Al in cotyledons of corn seedlings are indicative of the accumulation of these minerals from the plant environment. In both cases, the actual amounts of Fe and Al more than doubled in seedlings as compared to that found in the whole grain.

MATERIALS AND METHODS

Selection of Cultivars

Three soybean cultivars (Amsoy 71, Corsoy, and Hark) were grown in sand medium in greenhouse experiments. These cultivars were selected from among 9 (Table 1) tested in preliminary trials; selection was based upon their germination in a growth chamber and a sand culture where either deionized water or Complete Hoagland Solution (Table 2) was added.

Table 1. Soybean cultivars and cultivar characteristics

Cultivar	Parentage	Maturity group	Stem growth habit
Amsoy 71	Amsoy x (Blackhawk x Harosoy)	II	Indeterminate
Coles	Hark x (Provar x Magna x Disoy)	I	Indeterminate
Corsoy (II)	Harosoy x Capital	II	Indeterminate
Elf	Williams x Ransom	III	Determinate
Harcor	Corsoy x (Corsoy x Harosoy 63)	II	Indeterminate
Hark	Hawkeye x Harosoy	I	Indeterminate
Oakland	L66L-137 x Calland	III	Indeterminate
Wayne	L49-4091 x Clark	III	Indeterminate
Williams	Wayne x (Clark x Adams)	III	Indeterminate

The procedures used by the Iowa State University Seed Laboratory for testing germination and seedling vigor were used and are described below.

Table 2. Complete Hoagland Solution[a]

Compound	Concentration of stock solution, (M)	Concentration of stock solution, g/liter	Volume of stock solution per liter of final solution, ml
		Macronutrients	
KNO_3	1.00	101.10	6.0
$Ca(NO_3)_2 \cdot 4H_2O$	1.00	236.10	4.0
$NH_4H_2PO_4$	1.00	115.08	2.0
$MgSO_4 \cdot 7H_2O$	1.00	246.49	1.0
		Micronutrients[b]	
KCl	0.0500	3.728	
H_3BO_3	0.0250	1.546	
$MnSO_4 \cdot H_2O$	0.0020	0.338	1.0
$ZnSO_4 \cdot 7H_2O$	0.0020	0.575	
$CuSO_4 \cdot 5H_2O$	0.0005	0.125	
H_2MoO_4 (85% MoO_3)	0.0005	0.081	
Fe-EDTA[c]	0.0200	6.922	1.0

[a]After Epstein (1972), modified.

[b]A combined stock solution is made up containing all micronutrients except iron.

[c]Ferrous dihydrogen ethylenediamine tetraacetic acid.

Growth chamber tests

Three paper towels (26 x 61 cm) are used for each replicate of the test. Plastic waste baskets (18 x 28 x 30 cm) are used as containers. Partitions are made by punching holes in the sides of the basket and drawing light copper wire through the holes across the basket. If the holes and wires are properly placed, a maximum of 12 rolled towels may be placed in each container.

Clear polyethylene bags (41 x 61 cm) with an opening sufficiently large to fit over the basket are used to keep moisture in the containers.

Two towels are dipped in water and allowed to drip dry. The towels should be wet, but a water film should not appear if the towels are pressed with the thumb. The two towels are laid on a table and two rows each of 25 seeds (1 cm apart in the row) are placed on the towels. The top row should be approximately 4 cm below the top, the second row 8 cm below the top. The seeds are oriented with the radical end towards the bottom of the towel and the germ side of the seed down. A third dampened (drip dry) towel is placed over the seeds and the three towels loosely rolled. An elastic band is loosely fitted over the roll below the seeds. Each rolled towel is placed into the container with the seeds towards the top of the container. A polyethylene bag is pulled down over the container. At least 30 cm of the bag should protrude above the container so the seedlings will have plenty of room to develop. An elastic band is slipped around the container and bag to hold the bag to the container and prevent loss of moisture. The containers are placed in dark growth chambers at 25 ± 1 °C for seven days.

At the end of seven days, the towels are removed and a germination count made. The seeds are cut free from the normal seedlings using a razor blade; and the normal seedlings are placed in coin envelop (one for each replication) and dried in an oven at 80°C for 24 hours. The dried seedlings are then weighed, and the total weight of normal seedlings per towel divided by the number of seedlings to obtain the average seedling growth rate.

Sand germination tests

Four plastic trays (23 x 51 x 4 cm) were filled with white silica sand and wet up in the greenhouse. The sand had been washed with 1.5 N HCl and rinsed with deionized water until the rinse water tested negative for chlorine by the silver-nitrate test. Twenty-five seeds of each of the 9 cultivars mentioned earlier were sown in rows 5 cm apart. Two trays were treated with deionized water while the other two trays were treated with complete Hoagland Solution. A moist environment was maintained in the sand by daily application of the respective treatment for seven days. At the end of seven days, a count was made of normal seedlings in each tray. The total number of normal seedlings was expressed as a percentage of the total number of seeds sown to determine the germination percentage of each cultivar.

Based upon results from both growth chamber and sand seedbed experiments, a decision was made to select the three cultivars which consistently showed high germination and seedling vigor. Using these criteria, Amsoy 71, Corsoy, and Hark cultivars were selected for the experiments reported in this thesis.

Greenhouse Experiment

The experiments were conducted in the greenhouse. During the fall and winter, 1000 watt bulbs were used to supply 14-hour day lengths. The room was maintained at 25-28^{o}C. Fans were used to enhance air circulation in the room. A false ceiling of clear plastic was erected above the experimental area to prevent contamination caused by leaks in the roof. One layer of 4 mil clear plastic was placed inside of the south walls to provide shading from the intense direct afternoon sunshine.

The plants were grown in well-drained, white silica sand which had been sifted through a 2.0 mm sieve. The sand was acid washed, one pot at a time, with 500 ml of 1.5 N NCl. Approximately 790 g of dry sand was placed in the column of an expired deionizing cartridge. The acid was poured on the sand and allowed to soak through. The sand was then rinsed with deionized distilled water until the silver nitrate test for chlorine proved negative.

The washed sand was placed in white, plastic, DOW cups (8 cm high, 11.5 cm wide at the top). There were 4 pots per treatment - one pot for each stage of sampling (60 be described later). Four holes were pierced in the bottom of each pot to facilitate drainage. The cups were placed on plywood boards which covered the surface of the greenhouse bench filled with soil to prevent pots from having contact with the soil.

A randomized block design was used in all three experiments. There were 3, 2, and 4 replications for Series 1, 2, and 3, respectively. The treatments of the 2^2 or 2^3 factorial are shown in Table 3.

Table 3. Treatments used in individual experiments and parts of the study[a]

Treatment	Series I		Series II		Series III		
	Ca-Mn-Hoag Expt.	B-Hoag Expt.	Ca-Mn-Hoag Expt.	Ca-Mg-Hoag Expt.	Ca-Mn-Hoag Expt.	B-Hoag Expt.	Ca-Mg-Hoag Expt.
H_2O	X	X	X	X	X	X	X
Ca	X		X	X	X		X
Mn	X		X		X		
B		X				X	
Mg				X			X
Ca + Mn	X		X		X		
Ca + Mg				X			X
Hoag	X	X	X	X	X	X	X
Hoag-Ca	X		X	X	X		X
Hoag-Mn	X		X		X		
Hoag-B		X				X	
Hoag-Mg				X			X
Hoag-(Ca + Mn)	X		X		X		
Hoag-(Ca + Mg)				X			X

[a]Hoag indicates Hoagland Solution, Expt. indicates experiment.

The sand in each pot was thoroughly soaked with the appropriate treatment before planting. Fifteen beans were planted in each pot at a depth of approximately 2.5 cm. The sand was maintained in a moist condition by regular application of deionized water or the appropriate nutrient solution.

Nutrient solution was applied on the surface of the sand in each pot and allowed to percolate through the sand medium. Approximately 50 ml of nutrient solution or water was applied per pot per application. In general, one application per day was adequate. To minimize salt accumulation in the medium, every pot was treated with deionized water on alternate days. On these days, 75 ml of water per pot was used instead of the usual 50 ml of nutrient solution.

The seedlings were allowed to grow from emergence until the second trifoliates were fully unfolded. There were 4 times or stages of sampling between planting and the second trifoliate stage (Table 4). These stages were identified by us specifically for these experiments. The plants were allowed to grow until 9 out of 15 plants in each pot had attained sufficient growth to meet the criteria described in Table 4.

At each sampling the contents of a pot were placed in a sieve and washed with deionized, distilled water until the plants were clean of sand particles. Using a razor blade, the cleaned plant material was separated into three parts--shoots (including leaves, stems and petioles), roots and cotyledons--to facilitate studying the patterns of nutrient distribution in the various parts. Cotyledons were severed at their point of

Table 4. Identification and description of sampling stages

Sampling stage	Days after planting Average	Range	Degree of development
1	1	1-4	Pre-emergence; cotyledons swollen to about twice original size; radicle extending; sand cracking.
2	7	4-12	Emergence; cotyledons turning green; radicle elongation.
3	12	7-18	Unifoliate leaves unfolding; seedlings 2 to 3 inches tall.
4	19	17-31	2nd trifoliate leaves unfolding; seedlings 4 to 6 inches tall.

contact with the stem. The shoot-root demarcation was made at the ground level, which on the plant was identifiable by darkening of the stem portion above. Adventitious roots attached above this point were severed and included with the roots. Each part was placed in a coin envelop and dried at 65°C for 48 hours. After removal from the oven, the samples were allowed to equilibrate to room temperature and then weighed to determine the dry matter (mg/plant).

After weighing, the dried plant samples were ground, using a 40-mesh screen, to prepare them for chemical analyses. In order to obtain sufficient material for the analyses decided upon, composite samples were made for the cotyledons by combining samples from the different replications before grinding. This gave the necessary 0.5 g or more which was the minimum required for conducting all the analyses. Using the same procedure and for the same reasons, composite samples were made for sampling stages 1 and 2 for root and shoot samples. The ramifications of this will be discussed later in this thesis.

Portions of each sample were analyzed for P, K, Ca, Mg, Mn, Na, Fe, B, Cu, Zn, and Al by the Research-Extension Analytical Laboratory, Ohio Agricultural Research and Development Center, Wooster, Ohio.

RESULTS

Dry weights of roots (ROWT), shoots (SHWT), cotyledons (COWT), and of the whole plant (TWT); and the amounts of P, K, Ca, Mg, Mn, and B in each plant part, due to nutrient solutions used, were determined and are presented in this section. Data on other nutrients (Al, Cu, Fe, Na, and Zn) were also collected and are shown in Table B-2 in the Appendix.

Ca-Mn-Hoagland Experiment I

Dry weights

The analyses of variance over all four stages of sampling for the variables TWT, ROWT, SHWT, and COWT are summarized in Table 5. Average dry weights for each stage of sampling are presented in Table A-1 of the Appendix. The experimental results showing dry weights for individual replications are given in Appendix B (Table B-1).

The average dry weights of the three plant portions and the total dry weights of seedlings at the different times of sampling, as influenced by the different nutrient solutions are shown in Figure 1. The letters C, R, S, and T are used to designate cotyledons, roots, shoots, and total, respectively, in this and subsequent figures. Treatment names appear above the appropriate graphs in this and subsequent figures.

With respect to the total dry matter produced and in terms of its relative amounts in the plant parts studied, there was a wide variability in dry matter accumulation among treatments. The treatments used in this experiment may be categorized into three groups based on total dry matter

Table 5. **Analyses of variance of root weight (ROWT), shoot weight (SHWT), cotyledon weight (COWT), and total plant weight (TWT) -- Ca-Mn-Hoag Experiment I**

Source	DF	MS	F value	P>F
		ROWT		
Total	95	0.95		
Rep	2	0.54	3.82	.0272*
Stage	3	13.16	93.36	.0001**
Trt	7	2.83	20.11	.0001**
Ca	(1)	13.58	96.36	.0001**
Mn	(1)	0.92	6.56	.0127*
Ca x Mn	(1)	0.00	0.01	ns
Hoag	(1)	0.04	0.30	ns
Ca x Hoag	(1)	0.06	0.45	ns
Mn x Hoag	(1)	2.61	18.55	.0001**
Ca x Mn x Hoag	(1)	2.61	18.55	.0001**
Trt x Stage	21	0.99	7.06	.0001**
Error	62	0.14		
		SHWT		
Total	95	0.50		
Rep	2	1.11	20.43	.0001**
Stage	3	9.53	176.45	.0001**
Trt	7	1.00	18.53	.0001**
Ca	(1)	1.76	32.50	.0001**
Mn	(1)	0.17	3.09	.0838†
Ca x Mn	(1)	0.00	0.00	ns
Hoag	(1)	5.00	92.52	.0001**
Ca x Hoag	(1)	0.07	1.37	ns
Mn x Hoag	(1)	0.00	0.03	ns
Ca x Mn x Hoag	(1)	0.01	0.19	ns
Trt x Stage	21	0.29	5.46	.0001**
Error	62	0.05		

*Significant at 0.05 level in this and subsequent tables.

**Significant at 0.01 level in this and subsequent tables.

†Significant at 0.10 level in this and subsequent tables.

nsNonsignificant.

Table 5. (Continued)

Source	DF	MS	F value	P>F
		COWT		
Total	95	0.07		
Rep	2	0.61	52.98	.0001**
Stage	3	1.65	143.77	.0001**
Trt	7	0.09	1.15	ns
Ca	(1)	0.00	0.36	ns
Mn	(1)	0.00	0.01	ns
Ca x Mn	(1)	0.00	0.06	ns
Hoag	(1)	0.02	1.33	ns
Ca x Hoag	(1)	0.02	1.61	ns
Mn x Hoag	(1)	0.02	2.07	ns
Ca x Mn x Hoag	(1)	0.03	2.60	ns
Trt x Stage	21	0.00	0.48	ns
Error	62	0.01		
		TWT		
Total	95	1.99		
Rep	2	5.92	26.72	.0001**
Stage	3	30.25	136.62	.0001**
Trt	7	5.33	24.07	.0001**
Ca	(1)	24.45	110.45	.0001**
Mn	(1)	1.85	8.34	.0053**
Ca x Mn	(1)	0.00	0.00	ns
Hoag	(1)	6.57	29.67	.0001**
Ca x Hoag	(1)	0.01	0.80	ns
Mn X Hoag	(1)	2.03	9.18	.0036**
Ca x Mn x Hoag	(1)	2.39	10.80	.0017**
Trt x Stage	21	1.70	7.70	.0001**
Error	62	0.22		

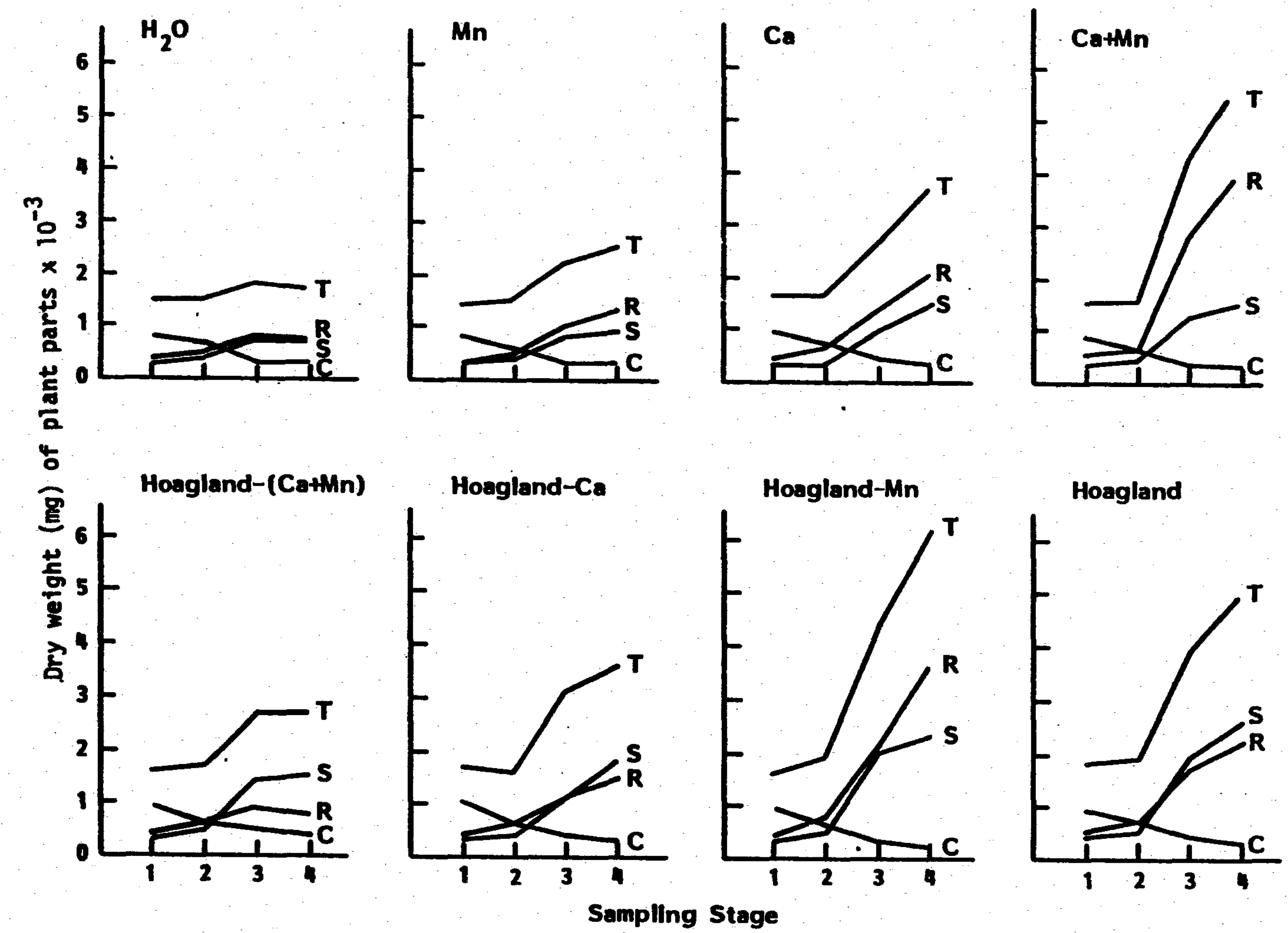

Figure 1. Variations in total dry weights (T), and dry weights of roots (R), shoots (S), and cotyledons (C) of soybean seedling treated with different nutrient solutions

produced. In Group I, consisting of H_2O, Mn, and Hoagland - (Ca + Mn), there was no significant increase in total dry weight. The maximum increase in total dry weight occurred where Ca + Mn, Hoagland, and Hoagland - Mn were used (Group III). Group II consisted of Ca and Hoagland - Ca where the total dry matter produced was intermediate with respect to the two groups mentioned above.

There was little difference in total dry weight at the first and second times of sampling, for all treatments. However, at the third and fourth times of sampling TWT differed significantly, except for treatments in Group I (H_2O, Mn, and Hoagland - (Ca + Mn)). The discussions on differences in TWT will focus largely on the third and fourth times of sampling.

In general, TWT increased materially due to treatments if the solutions contained Ca or Ca and Mn. This was true for both Hoagland and H_2O solution treatments. To the contrary, substantially lower TWT was produced with the exclusion of both Ca and Mn from Hoagland solution or by supplying only one of the two nutrients in water solution.

Irrespective of the treatment used, COWT decreased with successive stages of sampling. The rate and amount of decline in COWT was essentially the same for all 8 treatments, changing from an average of about 900 mg at Stage 1 to around 300 mg at Stage 4. On a percentage basis, COWT averaged about 55 percent of TWT at Stage 1 but accounted for less than 10 percent of TWT at Stage 4. Thus, the relative amount of total dry weights found in the cotyledons was not affected by the treatments used in this study.

The proportions of TWT found in the roots (ROWT) and shoots (SHWT) varied with treatment and with stage. In seedlings grown where only H_2O was used, the ratio of ROWT to SHWT remained practically unchanged over the four times of sampling. Disregarding samplings at Stages 1 and 2 where root:shoot ratio was about equal for all treatments, there was slightly more than a 1:1 ratio of roots to shoots (in favor of roots) except where Ca + Mn and Hoagland - (Ca + Mn) were used. Where Ca + Mn was used, there was better than a 2:1 ratio of roots to shoots; and where Hoagland - (Ca + Mn) was used there was a 1:1.5 ratio of roots to shoots.

There was a differential response of roots and shoots to Hoagland relative to H_2O treatments. The average root dry weights were about 2000 mg for both groups of treatments, meaning the change in ROWT, when averaged, was equal for both groups. The average shoot weights were approximately 1,200 mg and 2,000 mg for H_2O and Hoagland treatments, respectively. The SHWT for Hoagland treatments were consistently nearly twice as much as that obtained for their H_2O equivalents. In brief, the effect of Hoagland on dry weight relative to H_2O was significant for shoots and in interactions for roots (see Table 5).

Mineral nutrients

Phosphorus The average P content of the seedlings (TP) and of the roots (PRO), shoots (PSH), and cotyledons (PCO) are summarized in Table A-2 in the Appendix. The experimental results for individual replications are given in Table B-1, also in the Appendix. The analyses of variance over all four stages of sampling for the variables TP, PRO, PSH, and PCO are all summarized in Table 6.

Table 6. **Analyses of variance of PRO, PSH, PCO, and TP -- Ca-Mn-Hoagland Experiment I**

Source	DF	MS	F value	P>F
		PRO		
Total	95	95.97		
Rep	2	1.49	1.78	ns
Stage	3	3.63	4.34	0.0078**
Trt	7	1.68	2.01	0.0679†
Ca	(1)	0.71	0.84	ns
Mn	(1)	1.38	1.65	ns
Ca x Mn	(1)	0.02	0.03	ns
Hoag	(1)	6.80	8.14	0.0059**
Ca x Hoag	(1)	0.60	0.72	ns
Mn x Hoag	(1)	1.48	1.77	ns
Ca x Mn x Hoag	(1)	0.76	0.91	ns
Trt x Stage	21	0.88	1.06	ns
Error	62	0.84		
		PSH		
Total	95	7.81		
Rep	2	18.34	6.46	0.0028**
Stage	3	84.48	29.79	0.0001**
Trt	7	19.97	7.04	0.0001**
Ca	(1)	12.45	4.39	0.0402*
Mn	(1)	1.44	0.51	ns
Ca x Mn	(1)	0.44	0.16	ns
Hoag	(1)	121.00	42.67	0.0001**
Ca x Hoag	(1)	4.48	1.58	ns
Mn x Hoag	(1)	0.01	0.01	ns
Ca x Mn x Hoag	(1)	0.00	0.00	ns
Trt x Stage	21	6.48	2.28	0.0064**
Error	62	2.84		

Table 6. (Continued)

Source	DF	MS	F value	P>F
		PCO		
Total	95	3.52		
Rep	2	16.87	37.92	0.0001**
Stage	3	85.33	191.77	0.0001**
Trt	7	1.24	2.79	0.0137**
Ca	(1)	5.47	12.30	0.0008**
Mn	(1)	0.00	0.01	ns
Ca x Mn	(1)	0.01	0.03	ns
Hoag	(1)	0.04	0.08	ns
Ca x Hoag	(1)	1.80	4.05	0.0484*
Mn x Hoag	(1)	1.36	3.06	0.0853†
Ca x Mn x Hoag	(1)	0.00	0.01	ns
Trt x Stage	21	0.40	0.90	ns
Error	62	0.44		
		TP		
Total	95	8.71		
Rep	2	86.52	16.16	.0001**
Stage	3	10.24	1.91	ns
Trt	7	11.88	2.22	.0442*
Ca	(1)	0.12	0.02	ns
Mn	(1)	5.95	1.11	ns
Ca x Mn	(1)	0.16	0.03	ns
Hoag	(1)	73.64	13.76	.0004**
Ca x Hoag	(1)	2.39	0.45	ns
Mn x Hoag	(1)	0.03	0.01	ns
Ca x Mn x Hoag	(1)	0.88	0.17	ns
Trt x Stage	21	9.93	1.85	.0317*
Error	62	5.35		

Figure 2 shows the average P content of the three plant parts and for the total plants at the different stages of sampling as influenced by the different nutrient solutions. The variations in P concentration for the different times of sampling are shown in Figure 3.

There was very little change in the total amount of phosphorus found in the whole plant (TP). Among the components contributing to the significant Trt effect, only the main effect of Hoagland Solution was significant at the 0.01 level (see Table 6). This finding is further substantiated by the graphs in Figure 2. Close examination reveals that TP averaged about 8.38 mg for water treatments over four times of sampling. It declined slightly with stage or remained essentially unchanged. In Hoagland treatments, TP averaged about 9.53 mg over all stages and either remained the same or tended to increase with stage.

Further comparisons show that the largest variabilities in TP occurred where only water and Complete Hoagland treatments were used. In the former TP consistently declined with stage changing from about 9.4 mg at Stage 1 to about 6.9 mg at Stage 4. This was a loss of 2.50 mg or about 27 percent of the initial amount. Where Hoagland solution was used there was about a 41 percent increase in TP from 9.3 mg at Stage 1 to 15.7 mg at Stage 4. It should be noted that TP first decreased (Stages 1 to 2) and then increased at the two latter samplings.

There was little change in the P content of roots with times of sampling. In three of the eight treatments, PRO increased slightly with time. Two of these (Mn and Ca + Mn) were water solution treatments, the third being Complete Hoagland.

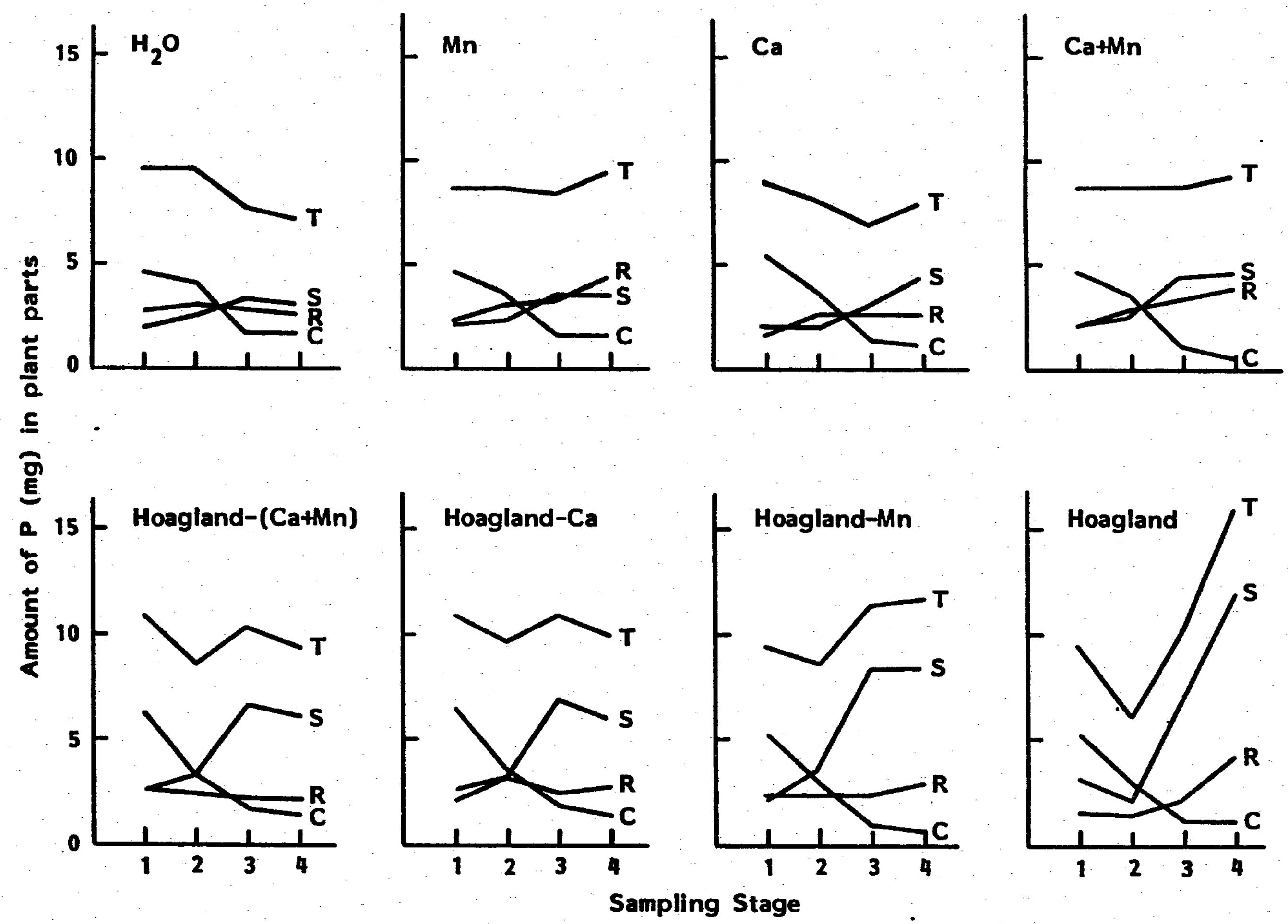

Figure 2. Variations in P content of whole plants (T), roots (R), shoots (S), and cotyledons (C), of soybean seedlings treated with different nutrient solutions

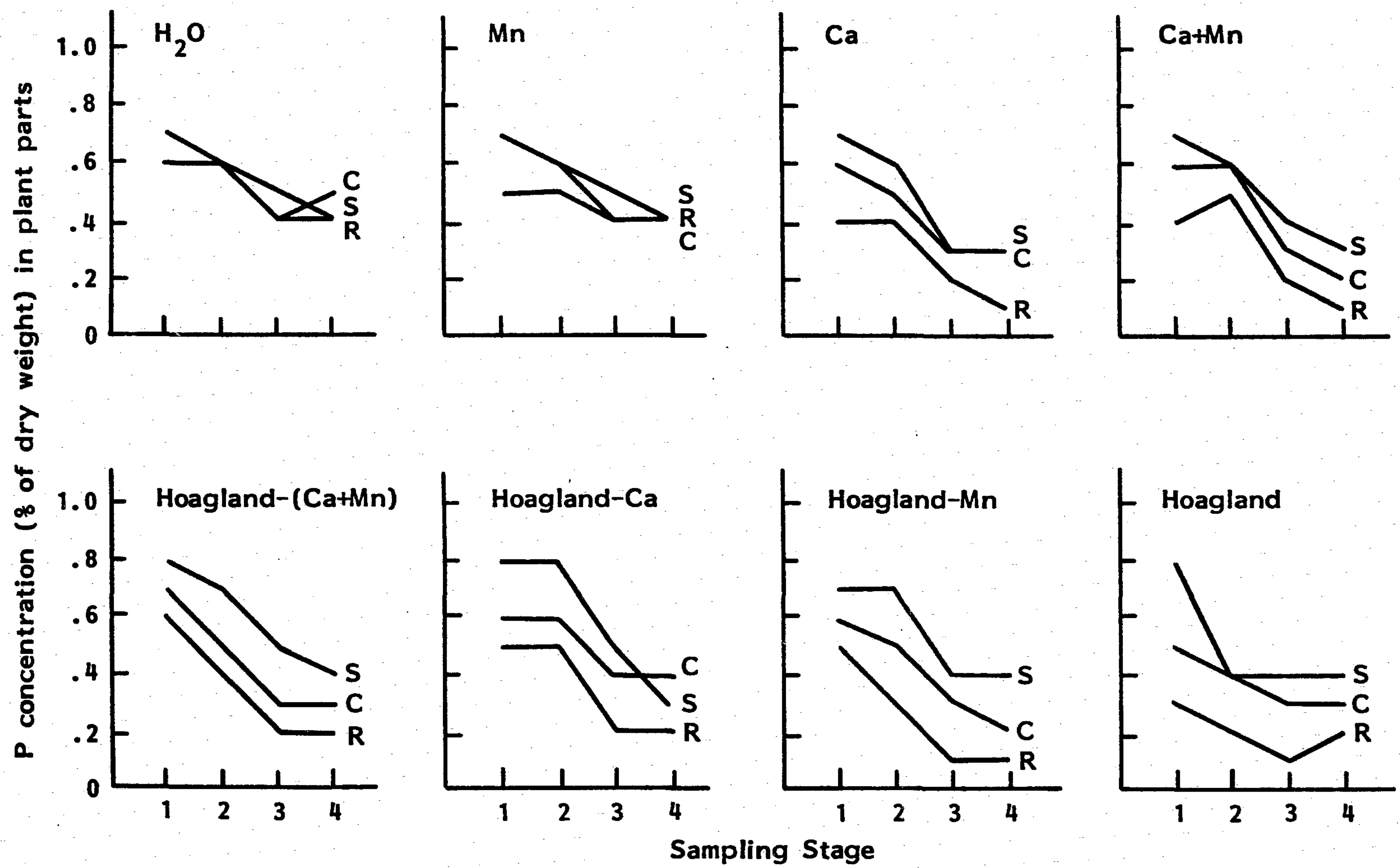

Figure 3. Variations in P concentration of roots (R), shoots (S), and cotyledons (C) of soybean seedlings treated with different nutrient solutions

There were large differences in P content of the shoot for water and Hoagland solution treatments. In the former, PSH increased only slightly. Except for Mn treatment, there was relatively more P found in the shoot than in the roots. Where Mn was used the proportion of P in the root was slightly larger than that found in the shoot at Stage 4.

There was a disproportionately larger amount of total P found in the shoots than in the roots for Hoagland solution treatments. These differences were smaller at earlier stages and increased with later stages. There was approximately a 3:2 ratio of PSH to PRO at Stage 1; and by Stage 4, this ratio had increased to about 3:1.

Figure 3 shows the concentration of P in the different plant portions as influenced by the different nutrient solutions. The values are expressed as a percentage of dry weights in the various plant parts. In general, P concentration in all plant parts declined with times of sampling for all treatments.

The graphs in Figure 3 fall into three categories based upon their magnitude and rates of change. In the first group consisting of H_2O and Mn, P concentration varied only slightly among plant parts and declined in no definite pattern. The decline in P concentration over time was from about 0.7 percent at Stage 1 to around 0.4 percent at Stage 4. This was the least decline when compared to that found in the other treatment groups.

In the second group consisting of Ca and Ca + Mn, P concentrations were intermediate, relative to the other groups. As in Group 1, P concentration was around 0.7 percent at Stage 1; but like Group 3, there was lower P concentration by Stage 4. Further, there were definite patterns shown for the changes in P concentration in the various parts, a feature not seen in Group 1 but one which is more evident in Group 3.

Group 3 consisted of Complete Hoagland Solution and the modified Hoagland solutions. These treatments differed in two ways. First, there was a higher P concentration in the shoots at Stage 1 (0.78 percent) and lower P concentration in the roots and cotyledons at Stage 4 (0.18 percent) in comparison to Groups 1 and 2. Secondly, the concentrations in different plant parts were well defined and separated from each other. Relative to other plant parts, P concentration was as follows: shoot > cotyledon > root over all stages except for Hoagland - Ca at Stage 4 where P concentrations in cotyledons were higher than in shoot.

<u>Potassium</u> Table A-3 in the Appendix summarizes the average K content data for the whole seedling (TK), the roots (KRO), the shoots (KSH), and for the cotyledons (KCO). Data for individual replications are given in Table B-1, also in the Appendix. Table 7 presents the analyses of variance for the variables TK, KRO, KSH, and KCO over all four times of sampling.

Figure 4 shows the K content (in mg) found in the whole seedling (TK) and in the various plant portions as influenced by the different nutrient solutions. Figure 5 shows the variations in K concentrations in different plant portions at each time of sampling as influenced by different nutrient solutions used.

Table 7. Analyses of variance of KRO, KSH, KCO, and TK -- Ca-Mn-Hoagland Experiment I

Source	DF	MS	F value	P>F
		KRO		
Total	95	212.09		
Rep	2	4.07	0.16	ns
Stage	3	1795.02	70.93	0.0001**
Trt	7	1290.52	51.00	0.0001**
Ca	(1)	503.48	19.91	0.0001**
Mn	(1)	129.48	5.12	0.0272*
Ca X Mn	(1)	51.37	2.03	ns
Hoag	(1)	7715.42	304.89	0.0001**
Ca x Hoag	(1)	555.48	21.95	0.0001**
Mn x Hoag	(1)	21.70	0.86	ns
Ca x Mn x Hoag	(1)	56.27	2.22	ns
Trt x Stage	21	197.76	7.81	0.0001**
Error	62	25.31		
		KSH		
Total	95	576.95		
Rep	2	439.53	12.17	0.0001**
Stage	3	6131.60	169.84	0.0001**
Trt	7	2774.43	76.85	0.0001**
Ca	(1)	95.92	2.66	ns
Mn	(1)	109.96	3.05	0.0859†
Ca x Mn	(1)	61.95	1.72	ns
Hoag	(1)	18949.57	524.90	0.0001**
Ca x Hoag	(1)	79.38	2.20	ns
Mn x Hoag	(1)	73.48	2.04	ns
Ca x Mn x Hoag	(1)	50.73	1.41	ns
Trt x Stage	21	660.82	18.30	0.0001**
Error	62	36.10		

Table 7. (Continued)

Source	DF	MS	F value	P>F
		KCO		
Total	95	36.02		
Rep	2	214.01	37.33	0.0001**
Stage	3	484.03	84.31	0.0001**
Trt	7	140.21	24.46	0.0001**
Ca	(1)	44.63	7.79	0.0070**
Mn	(1)	24.18	4.22	0.0442*
Ca x Mn	(1)	53.81	9.39	0.0032**
Hoag	(1)	622.80	108.63	0.0001**
Ca x Hoag	(1)	50.49	8.81	0.0043**
Mn x Hoag	(1)	169.87	29.63	0.0001**
Ca x Mn x Hoag	(1)	15.72	2.74	ns
Trt x Stage	21	9.85	1.72	0.0520†
Error	62	5.73		
		TK		
Total	95	1446.23		
Rep	2	1020.97	20.37	.0001**
Stage	3	9830.56	196.14	.0001**
Trt	7	9722.96	193.99	.0001**
Ca	(1)	1515.00	30.23	.0001**
Mn	(1)	717.29	14.31	.0004**
Ca x Mn	(1)	500.58	9.99	.0024**
Hoag	(1)	62725.61	1251.48	.0001**
Ca x Hoag	(1)	1566.87	31.26	.0001**
Mn x Hoag	(1)	869.80	13.76	.0004**
Ca x Mn x Hoag	(1)	345.58	6.89	.0109*
Trt x Stage	21	1651.91	32.96	.0001**
Error	62	50.12		

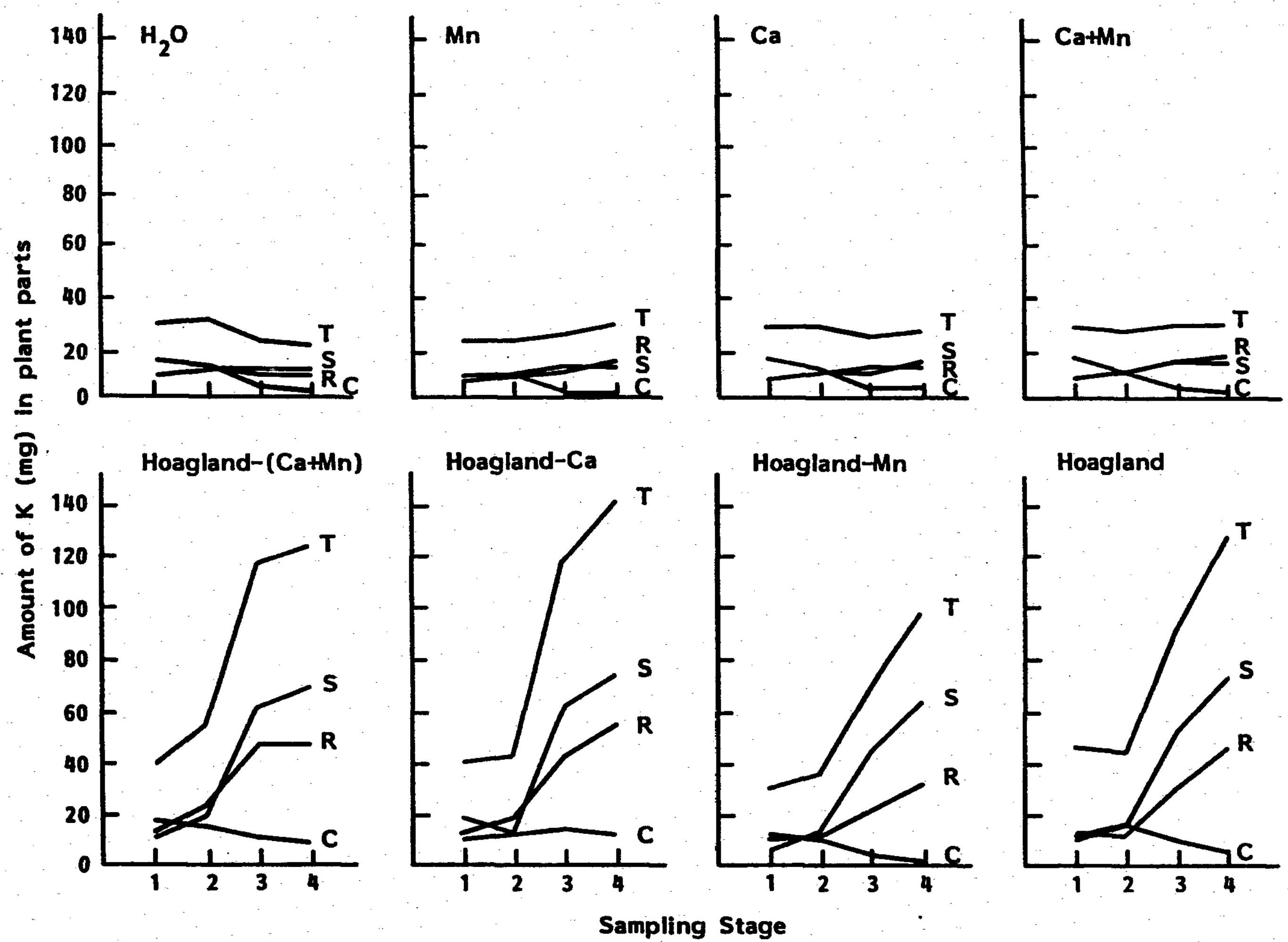

Figure 4. Variations in K content of whole plants (T), roots (R), shoots (S), and cotyledons (C) of soybean seedlings treated with different nutrient solutions

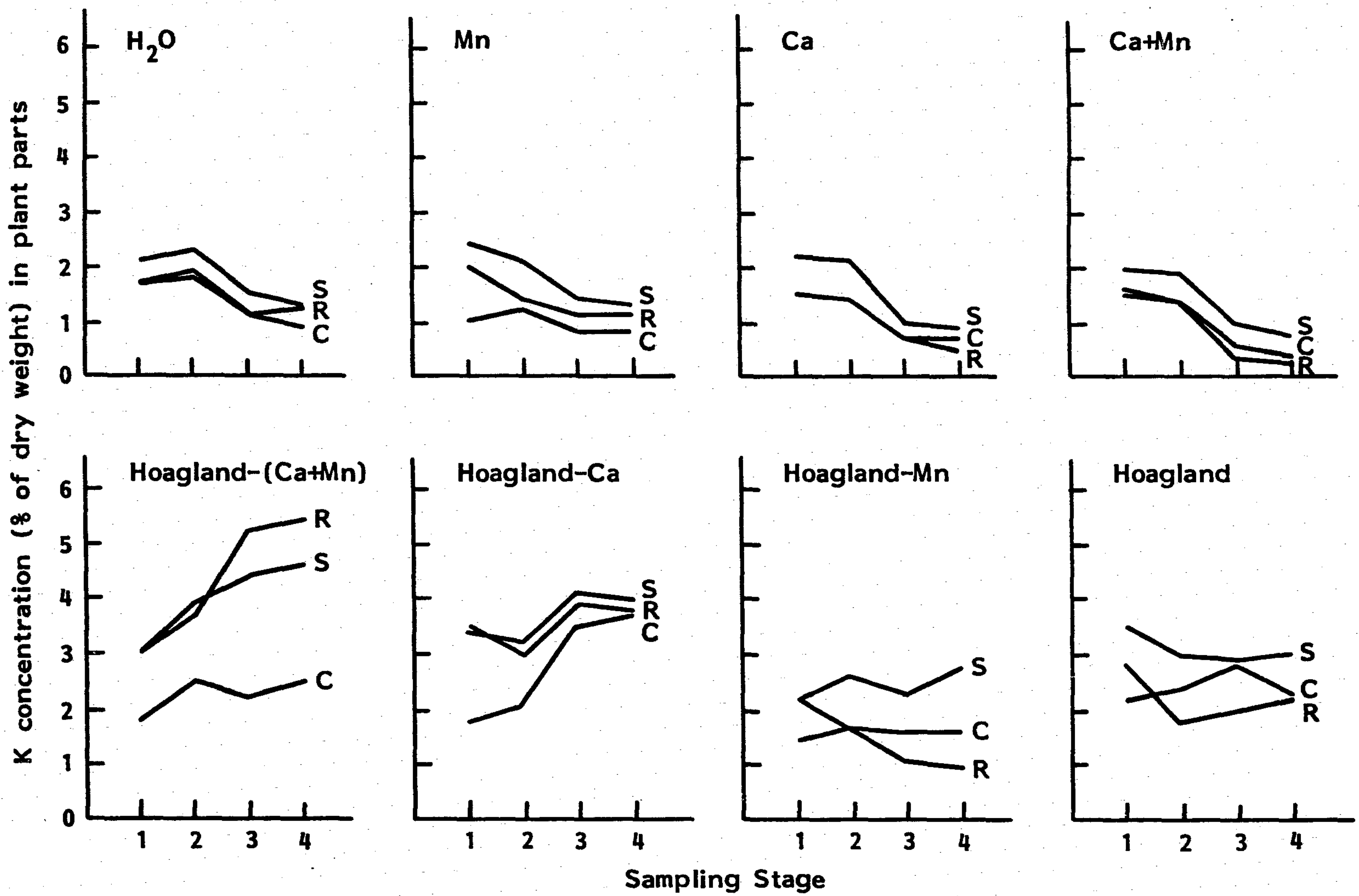

Figure 5. Variations in K concentration of roots (R), shoots (S), and cotyledons (C) of soybean seedlings treated with different nutrient solutions

There are sharp differences among the graphs shown in Figure 4. For Water Solution treatments (where no K was supplied) the amount of K was unchanged and there were significantly lower amounts of TK and K in the various plant parts compared to Hoagland treatments. The relative amounts of K in various plant parts were the same for water treatments and there was no difference among treatments within the group.

There were significant increases in TK, KRO, and KSH for Hoagland Solution treatments. These increases occurred after Stage 2. There was consistently a 3:2 ratio or more of KSH to KRO. The amount of K in the cotyledon declined in all but the Hoagland - Ca treatment where it remained essentially unchanged. The minimum TK, found in plants treated with Hoagland - Mn solutions, was significantly different from the other three treatments which were not different from one another. There was no difference in the amount of K found in the shoot for the four treatments; however, there was significantly lower K in the roots of plants treated with Hoagland - Mn.

Changes in the concentration of K in different plant portions were diverse. In Water Solution treatments, K concentration declined with stage. There was consistently higher K concentration in the shoots than in the roots or cotyledons; in the latter two, trends were inconsistent.

Among Hoagland Solution treatments there were two different trends shown. There were increases in the concentrations of K in roots, shoots, and cotyledons for plants which received Hoagland - Ca and Hoagland - (Ca + Mn) treatments. The increase in percent K found in the cotyledon was only marginal for the Hoagland - (Ca + Mn) treatment but substantial for the Hoagland - Ca treatment. There were significantly greater increases in percent K of both roots and shoots with Hoagland - (Ca + Mn) as compared to the Hoagland - Ca treatment.

In plants treated with Complete Hoagland and Hoagland - Mn, the concentration of K was either unchanged or declined slightly over the times of sampling. The only exception was a marginal increase in percent K of the shoot for plants which received the Hoagland - Mn treatment.

Calcium Average calcium content (in mg) of the seedlings (TCa) and of the roots (CaRO), and shoots (CaSH), and cotyledons (CaCO) as influenced by different nutrient solutions are shown in Figure 6 and in Table A-4 of the Appendix. The experimental data showing calcium content in each portion of the plant for individual replications are presented in Table B-1. Table 8 summarizes the analyses of variance for the variables TCa, CaRO, CaSH, and CaCO over all four stages of sampling. Figure 7 shows the fluctuations in calcium concentration in different plant parts due to each treatment over the four times of smapling.

There were large differences in the amount of calcium found in plants due to treatments which supplied Ca and those that did not. In the latter group, there was no change in TCa and the relative amounts of Ca in various plant portions were essentially the same. The treatments involved were H_2O, Mn, Hoagland - Ca, and Hoagland - (Ca + Mn). Treatments which supplied Ca included Ca, Ca + Mn, Hoagland - Mn, and Hoagland. There were significant increases in TCa, CaRO and CaSH and practically no change in

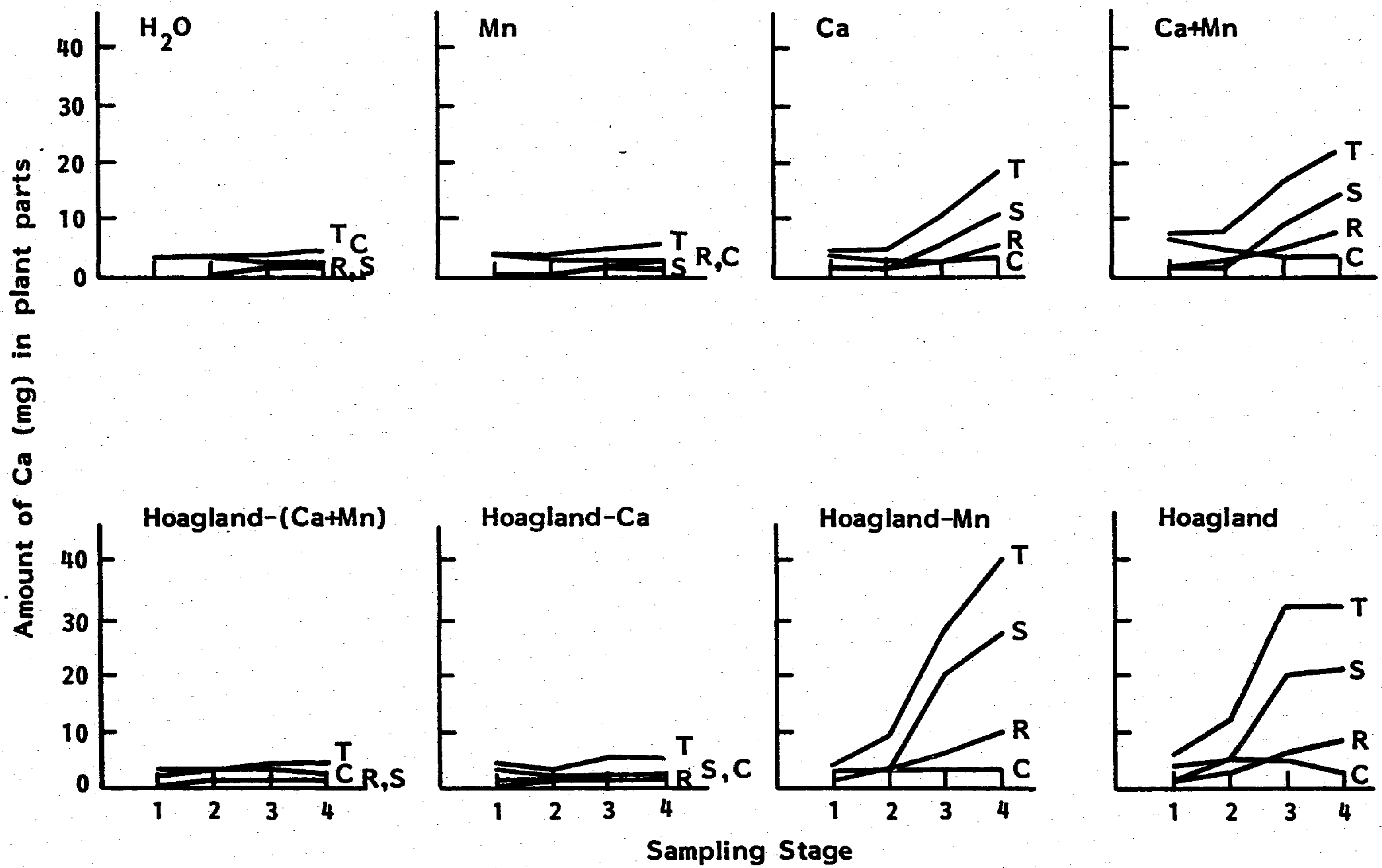

Figure 6. Variations in Ca content of whole plants (T), roots (R), shoots (S), and cotyledons (C) of soybean seedlings treated with different nutrient solutions

Table 8. Analyses of variance of CaRO, CaSH, CaCO, and TCa -- Ca-Mn-Hoagland Experiment I

Source	DF	MS	F value	P>F
		CaRO		
Total	95	7.12		
Rep	2	0.38	0.43	ns
Stage	3	68.64	77.70	0.0001**
Trt	7	38.45	43.53	0.0001**
Ca	(1)	224.46	254.12	0.0001**
Mn	(1)	2.03	2.03	ns
Ca x Mn	(1)	0.53	0.60	ns
Hoag	(1)	20.06	22.71	0.0001**
Ca x Hoag	(1)	16.66	18.86	0.0001**
Mn x Hoag	(1)	3.15	3.57	0.0636†
Ca x Mn x Hoag	(1)	2.26	2.56	ns
Trt x Stage	21	6.93	7.85	0.0001**
Error	62	0.88		
		CaSH		
Total	95	55.62		
Rep	2	5.72	1.44	ns
Stage	3	445.19	112.05	0.0001**
Trt	7	309.79	77.97	0.0001**
Ca	(1)	1474.35	371.07	0.0001**
Mn	(1)	1.06	0.27	ns
Ca x Mn	(1)	0.00	0.00	ns
Hoag	(1)	366.55	92.26	0.0001**
Ca x Hoag	(1)	313.58	78.92	0.0001**
Mn x Hoag	(1)	5.92	1.49	ns
Ca x Mn x Hoag	(1)	7.05	1.78	ns
Trt x Stage	21	72.48	18.48	0.0001**
Error	62	3.97		

Table 8. (Continued)

Source	DF	MS	F value	P>F
		CaCO		
Total	95	1.54		
Rep	2	16.74	28.37	0.0001**
Stage	3	2.15	3.65	0.0171*
Trt	7	6.61	11.20	0.0001**
Ca	(1)	25.78	43.71	0.0001**
Mn	(1)	10.18	17.26	0.0001**
Ca x Mn	(1)	9.14	15.50	0.0002**
Hoag	(1)	0.94	1.59	ns
Ca x Hoag	(1)	0.00	0.00	ns
Mn x Hoag	(1)	0.18	0.30	ns
Ca x Mn x Hoag	(1)	0.02	0.04	ns
Trt x Stage	21	1.11	1.88	0.0292*
Error	62	0.59		
		TCa		
Total	95	107.09		
Rep	2	35.25	4.53	.0145*
Stage	3	776.63	99.91	.0001**
Trt	7	655.03	84.26	.0001**
Ca	(1)	3417.22	439.60	.0001**
Mn	(1)	31.89	4.10	.0471*
Ca x Mn	(1)	14.40	1.85	ns
Hoag	(1)	604.84	77.81	.0001**
Ca x Hoag	(1)	476.87	61.35	.0001**
Mn x Hoag	(1)	21.40	2.75	ns
Ca x Mn x Hoag	(1)	18.59	2.39	ns
Trt x Stage	21	128.86	16.58	.0001**
Error	62	7.77		

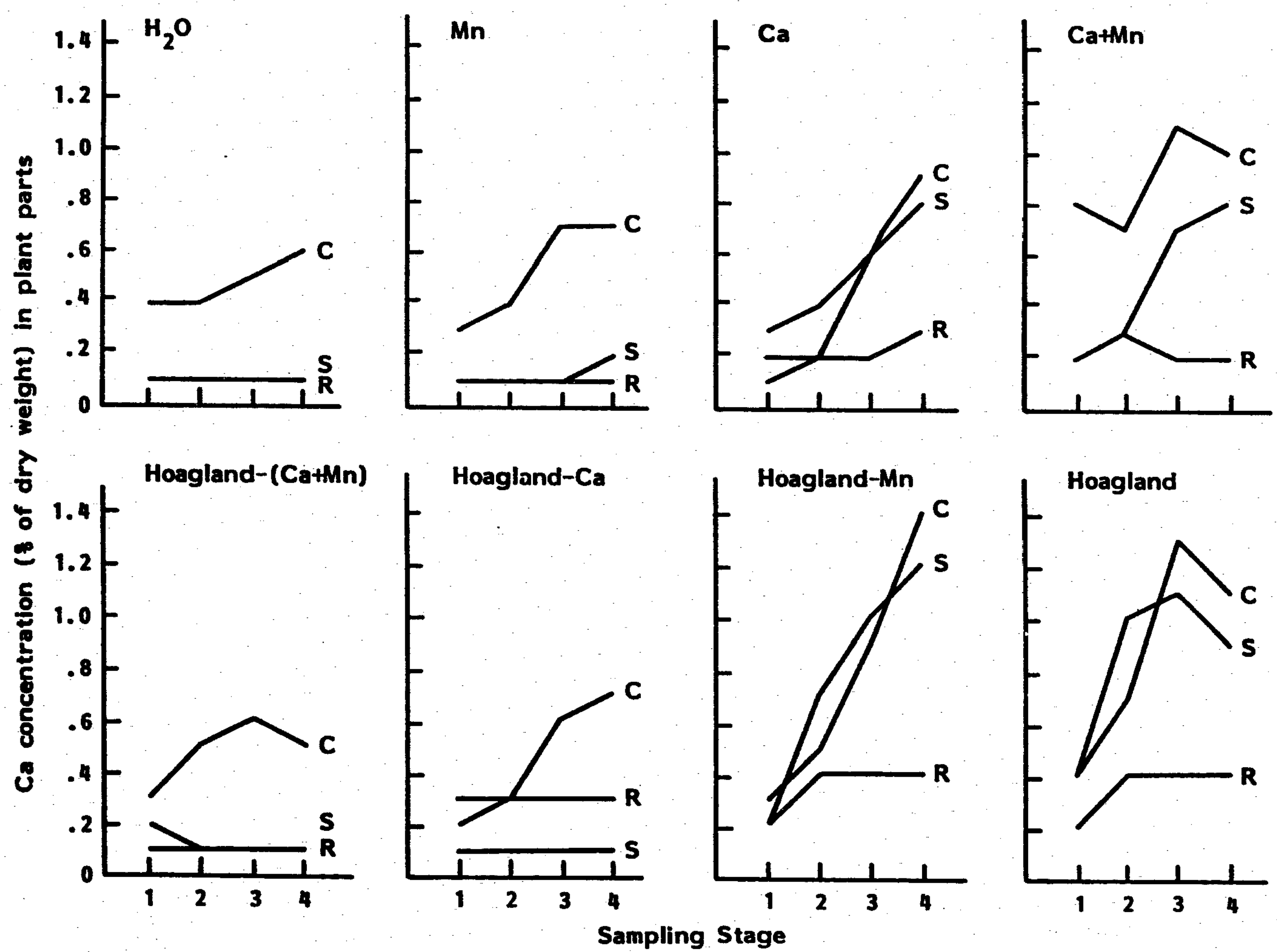

Figure 7. Variations in Ca concentration of roots (R), shoots (S), and cotyledons (C) of soybean seedlings treated with different nutrient solutions

CaCO. Further examination of this group revealed there was nearly twice as much TCa in plants grown with Hoagland Solution treatments that supplied Ca as was in plants grown with Water Solution treatments that supplied Ca.

Except for the Ca + Mn treatment which had a significantly high Ca content at Stage 1, there was no difference in Ca content of the cotyledon due to treatment. Despite this high level of Ca in the cotyledon at Stage 1, there was no difference in CaCO during later stages of sampling. It should be noted further that despite a moderate increase in CaCO with Complete Hoagland Solution at Stages 2 and 3, there was no difference in Ca content of the cotyledon overall as compared to other treatments. Overall, CaCO averaged 3.2 mg at Stage 1 and 2.5 mg at Stage 4. This means only 22 percent of CaCO was translocated between Stages 1 and 4.

Both Ca and Hoagland significantly influenced Ca content of the roots and shoots but Mn did not (see Table 8). However, in the cotyledon, Ca and Mn significantly affected Ca but Hoagland did not. The Trt x Stage interaction was significant at the 0.05 level in the cotyledons and at the 0.01 level in the roots and shoots.

Variations in the Ca concentration in various plant portions as influenced by different nutrient solutions are shown in Figure 7. There was an increase in Ca concentration with stage in the cotyledons for all treatments; the least fluctuations occurred in plants treated with H_2O and the largest in plants treated with Hoagland - Mn. Overall, Ca concentration increased with declining cotyledon weights.

There was little change in Ca concentration of the roots with stage of sampling for all treatments. Nevertheless, treatments could be categorized into two groups based on the level of Ca concentration found in the roots. Group I consisted of H_2O, Mn, and Hoagland - (Ca + Mn). All other treatments belonged to Group II. Ca concentration averaged 0.1 percent in roots of plants from Group I and about 0.4 percent for those from Group II over all stages of sampling. Only minor changes occurred in Ca concentration from one stage to the next for plants in both groups.

Treatments varied widely based upon the fluctuations of Ca concentration in the shoots; and could be grouped into three categories. In Group I, consisting of H_2O, Mn, Hoagland - Ca, and Hoagland - (Ca + Mn), Ca concentration in the shoot averaged 0.1 percent and generally remained unchanged over the four times of sampling. None of these four treatments supplied Ca. The second group of treatments included Ca and Hoagland - Mn. The complete Hoagland treatments constitute Group 3 in which Ca concentration in the shoots increased and then decreased. The two latter groups of treatments, unlike the first, supplied Ca; but differed in that Group 3 also contained Mn whereas Group 2 did not. The implications of these differences are discussed later.

Magnesium The average magnesium content of soybean seedlings and of various portions thereof due to different nutrient solutions are summarized in Table A-5 in the Appendix and are presented graphically in Figure 8. The experimental data showing Mg contents for individual replications at each stage of sampling are presented in Table B-1. The graphs in Figure 9 show the variations in Mg concentration at each stage of sampling as influenced by each nutrient solution.

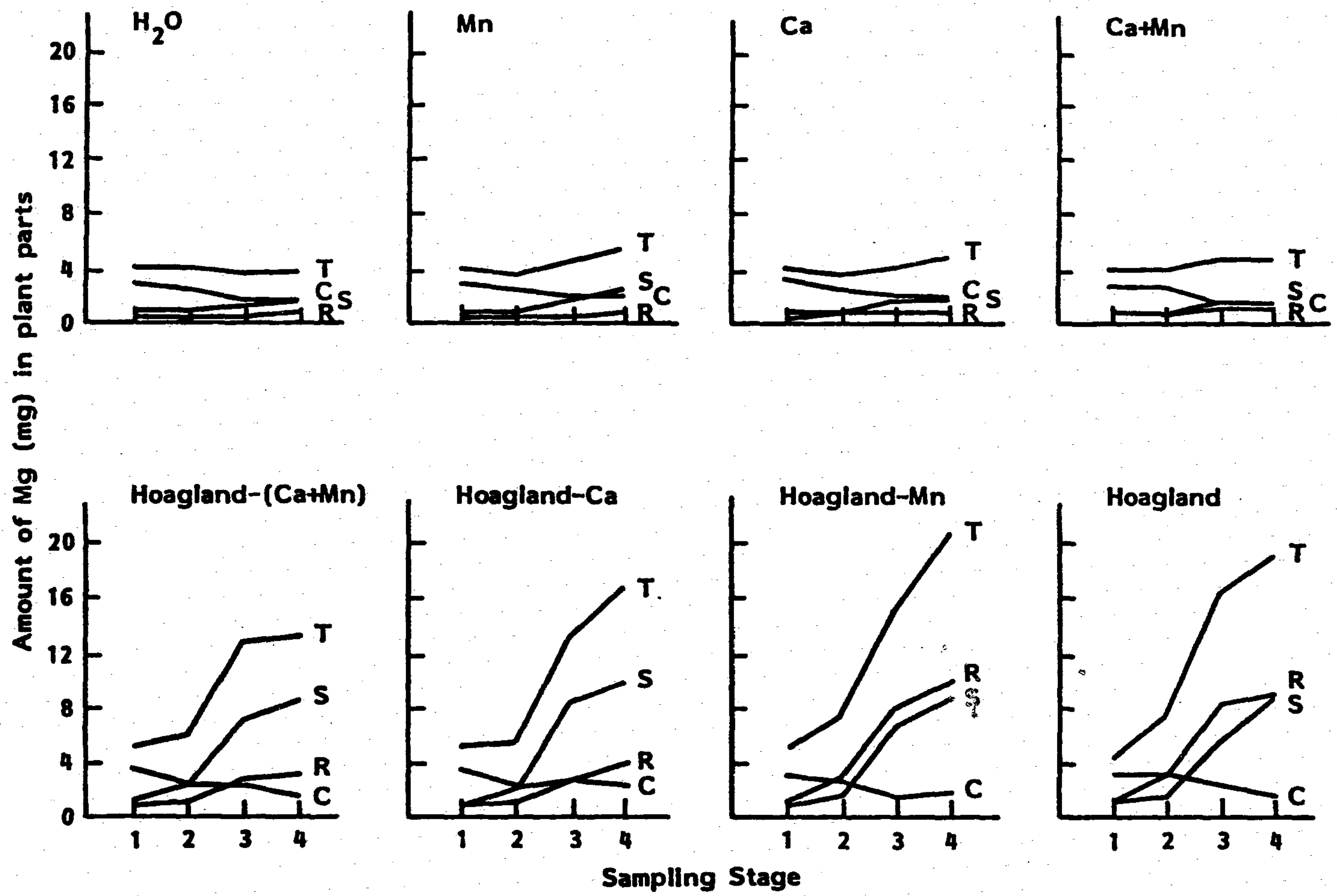

Figure 8. Variations in Mg content of whole plants (T), roots (R), shoots (S), and cotyledons (C) of soybean seedlings treated with different nutrient solutions

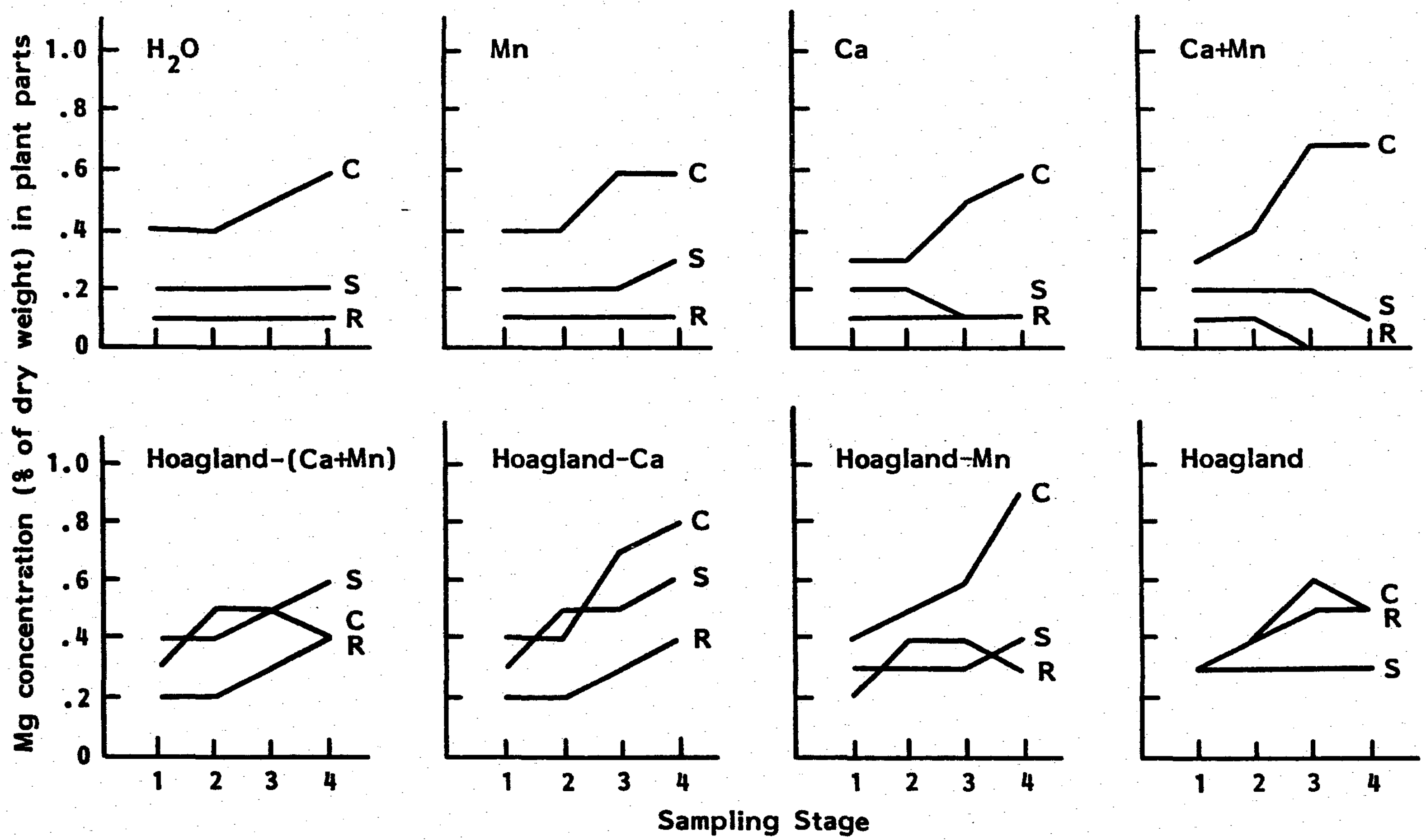

Figure 9. Variations in Mg concentration of roots (R), shoots (S), and cotyledons (C) of soybean seedlings treated with different nutrient solutions

Figure 8 shows that there was no difference in the total amounts of Mg found in the seedlings when magnesium was not supplied, as in the Water Solution treatments (H_2O, Mn, Ca and Ca +Mn). The relative amount of Mg in the various plant parts was also the same for all treatments. These findings were as expected since none of the treatments contained magnesium.

There were significant increases in the total amount of magnesium in the seedlings due to Hoagland Solution treatments. Larger increases occurred at the two latter stages of sampling than at the first two stages. Based on the amount of TMg in the seedlings, the treatments ranked as follows: Hoagland - Mn > Hoagland > Hoagland - Ca > Hoagland - (Ca + Mn). The trends of interest to us are that TMg tended to be lower when Ca alone or together with Mn was missing in the treatment. Deletion of Mn alone did not seem to adversely affect TMg in the seedlings. Table 9 shows that the main effect of Mn on TMg was not significant, meaning there was no difference in the total amount of Mg in seedlings in the presence or absence of Mn. Any differences observed could be explained or accounted for by other factors.

The relative proportion of Mg in plant parts for Hoagland Solution treatments varied with the presence or absence of Ca in the solution. There was a more even proportioning of Magnesium in roots and shoots when Ca was supplied in the treatment (Hoagland - Mn and Hoagland). But when Ca was absent from the treatment (Hoagland - (Ca + Mn) and Hoagland - Ca), there was about twice as much Mg in the shoot as was in the root. The graphs in Figure 8 show these relationships.

Table 9. **Analyses of variance of MgRO, MgSH, MgCO, and TMg -- Ca-Mn-Hoagland Experiment I**

Source	DF	MS	F value	P>F
		MgRO		
Total	95	8.16		
Rep	2	1.60	1.57	ns
Stage	3	48.19	47.19	0.0001**
Trt	7	54.77	53.52	0.0001**
Ca	(1)	76.42	74.68	0.0001**
Mn	(1)	0.03	0.03	ns
Ca x Mn	(1)	0.10	0.10	ns
Hoag	(1)	244.32	238.76	0.0001**
Ca x Hoag	(1)	62.05	60.64	0.0001**
Mn x Hoag	(1)	0.05	0.05	ns
Ca x Mn x Hoag	(1)	0.41	0.40	ns
Trt x Stage	21	8.62	8.42	0.0001**
Error	62	1.02		
		MgSH		
Total	95	9.59		
Rep	2	3.13	5.63	0.0057**
Stage	3	119.35	211.29	0.0001**
Trt	7	43.19	76.46	0.0001**
Ca	(1)	3.37	5.97	0.0174*
Mn	(1)	0.57	1.01	ns
Ca x Mn	(1)	1.52	2.69	ns
Hoag	(1)	293.91	520.34	0.0001**
Ca x Hoag	(1)	2.56	4.54	0.0371*
Mn x Hoag	(1)	0.00	0.01	ns
Ca x Mn x Hoag	(1)	0.38	0.68	ns
Trt x Stage	21	9.97	17.65	0.0001**
Error	62	0.56		

Table 9. (Continued)

Source	DF	MS	F value	P>F
		MgCO		
Total	95	0.66		
Rep	2	12.21	76.10	0.0001**
Stage	3	6.45	40.25	0.0001**
Trt	7	0.48	2.98	0.0093**
Ca	(1)	0.14	0.86	ns
Mn	(1)	0.40	2.51	ns
Ca x Mn	(1)	0.48	3.01	0.0878†
Hoag	(1)	1.67	10.44	0.0020**
Ca x Hoag	(1)	0.52	3.24	0.0768†
Mn x Hoag	(1)	0.10	0.62	ns
Ca x Mn x Hoag	(1)	0.03	0.20	ns
Trt x Stage	21	0.26	1.61	0.0756†
Error	62	0.16		
		TMg		
Total	95	28.61		
Rep	2	14.11	11.44	.0001**
Stage	3	237.61	192.67	.0001**
Trt	7	177.68	144.07	.0001**
Ca	(1)	42.68	34.60	.0001**
Mn	(1)	2.46	1.99	ns
Ca x Mn	(1)	5.02	4.07	.0480*
Hoag	(1)	1160.68	941.14	.0001**
Ca x Hoag	(1)	30.87	25.03	.0001**
Mn x Hoag	(1)	0.00	0.00	ns
Ca x Mn x Hoag	(1)	2.07	1.68	ns
Trt x Stage	21	31.26	25.35	.0001**
Error	62	1.23		

The amount of Mg in cotyledons due to Hoagland Solution treatments was similar to that for Water Solution treatments. It averaged about 3.4 mg at Stage 1 and declined to an average of 1.9 mg at Stage 4, a decline of 44 percent. This means less than 50 percent of Mg in the cotyledons at Stage 1 was translocated by Stage 4. This closely resembles trends seen with Ca and is unlike trends for P and K presented earlier.

Changes in percent Mg in different plant parts as influenced by different nutrient solutions are shown in Figure 9. The graphs show a complex relationship. In general, Mg concentration in the cotyledons increased with stage, averaging 0.35 percent at Stage 1 and about 0.64 percent at Stage 4 for all 8 treatments. The exceptions were with Hoagland and Hoagland - (Ca + Mn) where Mg concentrations in cotyledons increased during the first three stages and decreased thereafter.

There were large differences in Mg concentration in roots of plants treated with Hoagland treatments vs those that received Water treatments. Magnesium concentrations averaged about 0.1 percent and more than 0.2 percent for Water Solution and Hoagland Solution treatments, respectively. In the first group, MgRO averaged 0.1 percent and either remained constant or declined by the last stage; in the Hoagland group, MgRO averaged 0.2 percent at Stage 1 and increased thereafter. By Stage 4, MgRO averaged 0.4 percent for the group, a value more than four times the Mg concentration for Water treatments at Stage 4. The presence or absence of Ca in the treatment seemed to influence percent MgRO especially with Hoagland treatments. When Ca was deleted, Mg concentration tended to increase unabated. The presence of Ca seemed to limit the increase in Mg concentration in the root (see Figure 9).

Magnesium concentration in the shoots varied widely for the 8 treatments. When H_2O and Complete Hoagland treatments were used MgSH concentrations were 0.2 percent and 0.3 percent, respectively and remained constant throughout the sampling period. MgSH concentration was constant during the first three stages and increased by 0.1 percent at the fourth stage when Mn and Hoagland - Mn were used. The initial concentrations for these treatments were 0.2 percent and 0.3 percent, respectively. For the treatments Ca and Ca + Mn, MgSH was 0.2 percent at Stage 1 and 0.1 percent at Stage 4. The decline of 50 percent of the initial amount occurred between Stages 2 and 3 (for Ca) and between Stages 3 and 4 (for Ca + Mn). When Hoagland - Ca and Hoagland - (Ca + Mn) were used Mg concentration increased from 0.4 percent (Stage 1) to 0.6 percent at Stage 4.

Manganese Average Mn content in seedlings (in μg) at each stage of sampling as influenced by different nutrient solutions are presented in Table A-6 of the Appendix. Data for individual replications are shown in Table B-1, also in the Appendix. Figures 10 and 11, respectively, show the average Mn contents in μg and Mn concentrations in μg/g of dry weight for the various plant parts as influenced by the nutrient solutions used. The analyses of variance for the manganese variables are presented in Table 10.

The total amount of Mn in the seedlings, TMn, was affected differently by different nutrient solutions. TMn was slightly higher for Hoagland Solution treatments as a group than for their Water Solution equivalents. TMn averaged 40 μg and was practically unchanged for the

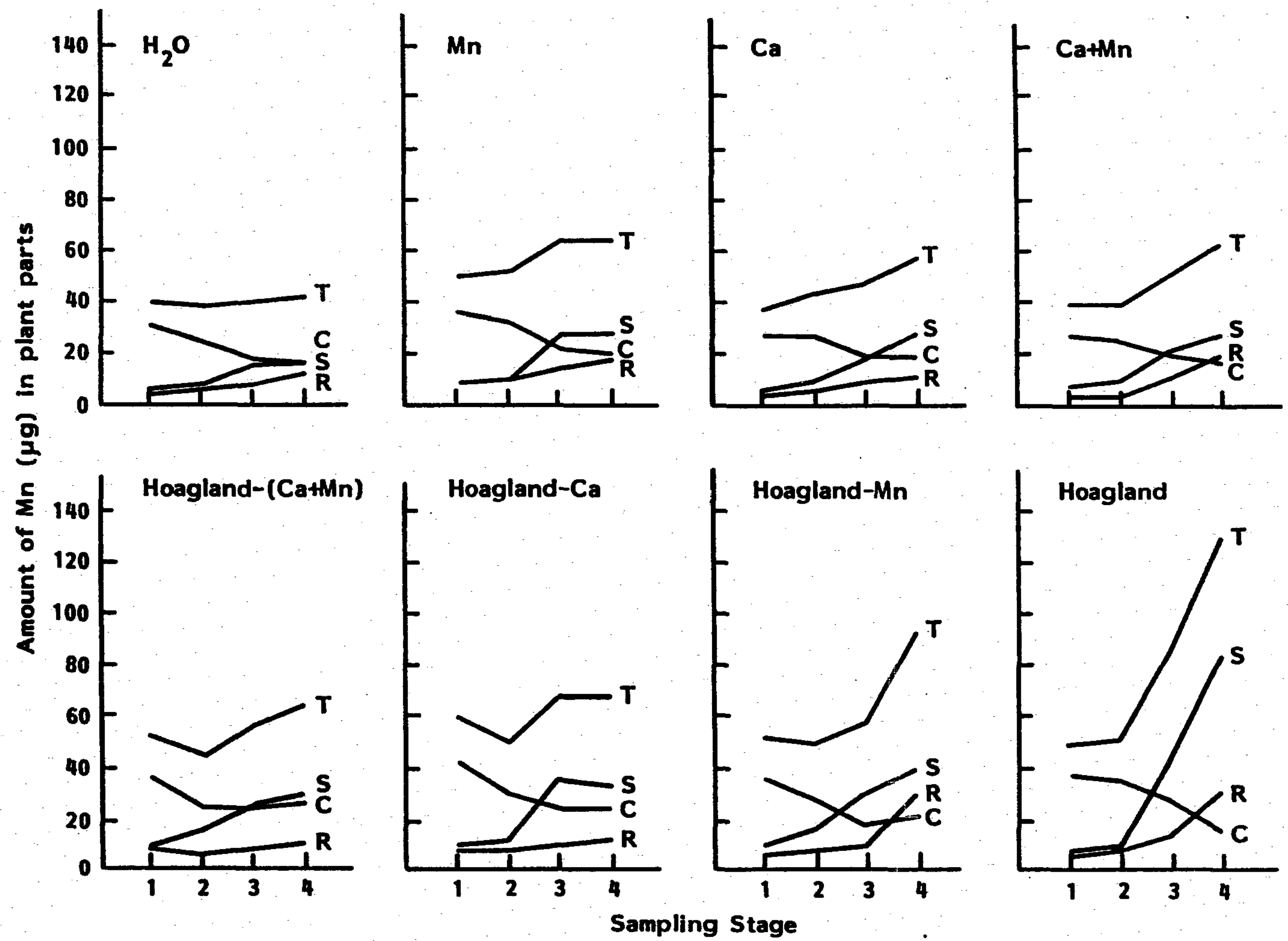

Figure 10. Variations in Mn content of whole plants (T), roots (R), shoots (S), and cotyledons (C) of soybean seedlings treated with different nutrient solutions

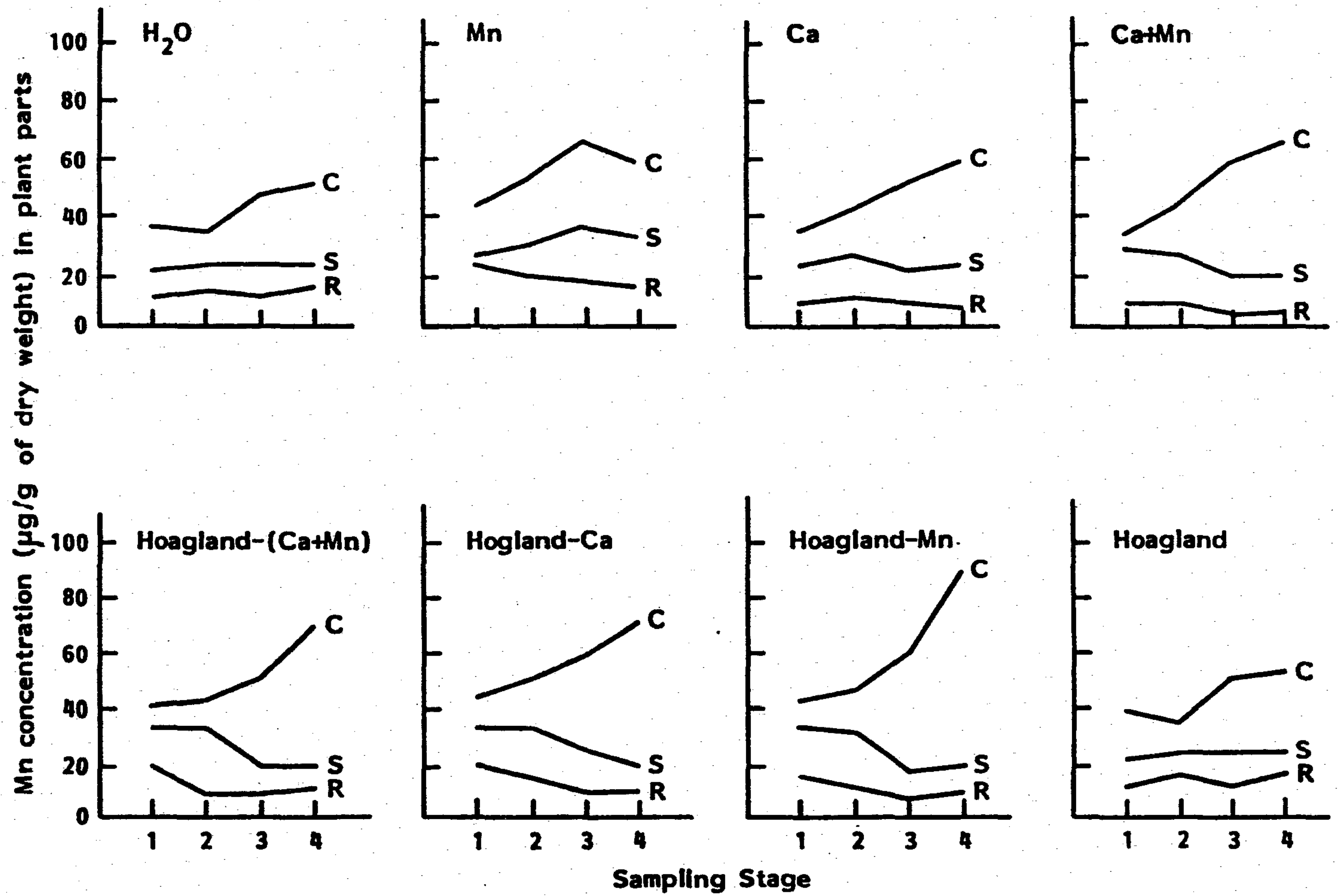

Figure 11. Variations in Mn concentration of roots (R), shoots (S), and cotyledons (C) of soybean seedlings treated with different nutrient solutions

Table 10. **Analyses of variance of MnRO, MnSH, MnCO, and TMn -- Ca-Mn-Hoagland Experiment I**

Source	DF	MS	F value	P>F
		MnRO		
Total	95	53.63		
Rep	2	0.37	0.02	ns
Stage	3	671.83	32.58	0.0001**
Trt	7	99.89	4.84	0.0002**
Ca	(1)	138.94	6.74	0.0118*
Mn	(1)	138.55	6.72	0.0119*
Ca x Mn	(1)	18.09	0.88	ns
Hoag	(1)	80.50	3.90	0.0529†
Ca x Hoag	(1)	291.59	14.14	0.0004**
Mn x Hoag	(1)	20.10	0.97	ns
Ca x Mn x Hoag	(1)	11.45	0.56	ns
Trt x Stage	21	52.44	2.54	0.0024**
Error	62	20.62		
		MnSH		
Total	95	285.17		
Rep	2	286.89	4.64	0.0133*
Stage	3	3935.64	63.59	0.0001**
Trt	7	678.44	10.96	0.0001**
Ca	(1)	546.98	8.84	0.0042**
Mn	(1)	876.59	14.16	0.0004**
Ca x Mn	(1)	23.85	0.39	ns
Hoag	(1)	2531.46	40.90	0.0001**
Ca x Hoag	(1)	362.90	5.86	0.0184*
Mn x Hoag	(1)	94.71	1.53	ns
Ca x Mn x Hoag	(1)	312.59	5.05	0.0282*
Trt x Stage	21	291.63	4.71	0.0001**
Error	62	61.89		

Table 10. (Continued)

Source	DF	MS	F value	P>F
		MnCO		
Total	95	80.93		
Rep	2	1133.76	70.83	0.0001**
Stage	3	1024.16	63.99	0.0001**
Trt	7	111.26	6.95	0.0001**
Ca	(1)	13.02	0.81	ns
Mn	(1)	215.79	13.48	0.0005**
Ca x Mn	(1)	61.49	3.84	0.0545†
Hoag	(1)	382.60	23.90	0.0001**
Ca x Hoag	(1)	0.33	0.02	ns
Mn x Hoag	(1)	0.04	0.00	ns
Ca x Mn x Hoag	(1)	105.53	6.59	0.0127*
Trt x Stage	21	27.50	1.72	0.0518†
Error	62	16.01		
		TMn		
Total	95	448.93		
Rep	2	2088.77	20.38	.0001**
Stage	3	3438.38	33.54	.0001**
Trt	7	1812.06	17.68	.0001**
Ca	(1)	996.47	9.62	.0028**
Mn	(1)	3143.61	30.67	.0001**
Ca x Mn	(1)	51.99	0.51	ns
Hoag	(1)	6216.71	60.64	.0001**
Ca x Hoag	(1)	1263.90	12.53	.0008**
Mn x Hoag	(1)	29.78	0.29	ns
Ca x Mn x Hoag	(1)	981.96	9.58	.0030**
Trt x Stage	21	434.04	4.23	.0001**
Error	62	102.51		

four times of sampling when only H_2O was used. It varied slightly, increasing with stage, for each of the other treatments. The amounts of TMn changed from 50 μg to 64 μg for Stages 1 and 4, respectively, when Mn alone was used. When Ca alone or Ca + Mn treatments were used, TMn values changed from 38 μg to 58 μg and from 40 μg to 64 μg, respectively, at Stages 1 and 4.

The changes in TMn due to Hoagland treatments differed from those presented above. The amounts were larger and varied with stage for each treatment. In general, TMn increased with stage for Hoagland treatments. When Hoagland - Ca and Hoagland - (Ca + Mn) were used, TMn averaged 54 μg and 62 μg, respectively for all four stages. In both cases, TMn declined between stages 1 and 2 and then increased. When Hoagland - Mn was used TMn changed only slightly during the first three stages but increased sharply between Stages 3 and 4. The largest increase in TMn occurred when Complete Hoagland treatment was used. It increased from 50 mg at Stage 1 to 130 mg at Stage 4. There was practically no change between Stages 1 and 2.

There was little translocation of Mn from the cotyledons of seedlings. The average amount of MnCO at Stage 4 was 56 percent of that found at Stage 1 for all 8 treatments. In other words, only about 44 percent of MnCO at Stage 1 was translocated or removed from the cotyledon at Stage 4. The percentage of MnCO at Stage 1 translocated by Stage 4 ranged from 31 percent with Hoagland - (Ca + Mn) to 59 percent for Hoagland. These results showed that Mn, like Ca, was not easily removed or translocated from the cotyledon, and that this removal was enhanced with Complete Hoagland.

Manganese content in the root (MnRO) increased with stage. There was an average of 6 μg of Mn in the roots at Stage 1; by Stage 4 the amount increased to 18 mg. Therefore, manganese content of the root increased on the average, three-fold from Stage 1 to Stage 4. The largest increase in MnRO occurred when complete Hoagland Solution was used; MnRO increased from 6 μg (Stage 1) to 32 μg (Stage 4). The smallest increase (8 μg to 10 mg) occurred when Hoagland - (Ca + Mn) was used. When only H_2O was used MnRO changed from 4 mg to 12 μg for Stages 1 and 4, respectively.

There were significant differences in Mn content of shoots (MnSH) due to different nutrient solutions. Manganese contents of the shoots increased with stage for all treatments. Overall, about a five-fold increase in MnSH occurred between Stage 1 and 4; the largest increase occurred when Complete Hoagland was used. There were larger increases in MnSH for Hoagland Solution treatments than occurred in H_2O Solution treatments. On a group basis, there was approximately five times as much Mn in the shoot at Stage 4 as was at Stage 1 for Hoagland treatments. For Water treatments the ratio was 4:1 for Stages 4 and 1, respectively.

Figure 11 shows the changes in Mn concentration (μg/g dry weight) in each plant part due to different nutrient solutions. Mn concentrations in different plant parts were consistently in the order cotyledons > shoots > roots. Manganese concentrations in the cotyledon increased with stage for all treatments; the largest increase occurred when Hoagland - Mn was used. The average Mn concentrations were 39 μg/g and 65 μg/g for Stages 1 and 4, respectively. The variations in Mn concentrations of the roots and shoots were not as large as in the cotyledons. Besides, in both roots and shoots Mn concentration declined with stage. Mn concentration in the roots averaged 13 μg/g and 10 μg/g at Stages 1 and 4, respectively. In the shoots, the average concentrations were 26 μg/g and 21 μg/g for stages 1 and 4, respectively. There was consistently a 2:1 ratio of Mn concentrations in the shoots as compared to the roots.

Boron Data for average B contents of total seedlings (TB) and of the roots (BRO), shoots (BSH), and cotyledons (BCO) are presented in Table A-7 in the Appendix. Figure 12 contains graphic representations of the average B contents (in μg) found in different plant parts as influenced by the different nutrient solutions used. The graphs in Figure 13 show the fluctuations in B concentration (μg/g) in the various plant portions as influenced by different nutrient solutions. Table 11 summarizes the analyses of variance for the variables TB, BRO, BSH and BCO.

The total amounts of B in seedlings were different for different treatments. The eight treatments could be categorized into three groups based on the amount of TB found in the seedlings. Group I consists of the four Water solution treatments (H_2O, Mn, Ca and Ca + Mn). Group II consists of Hoagland - Ca and Hoagland - (Ca + Mn). The third group consists of Hoagland - Mn and Complete Hoagland.

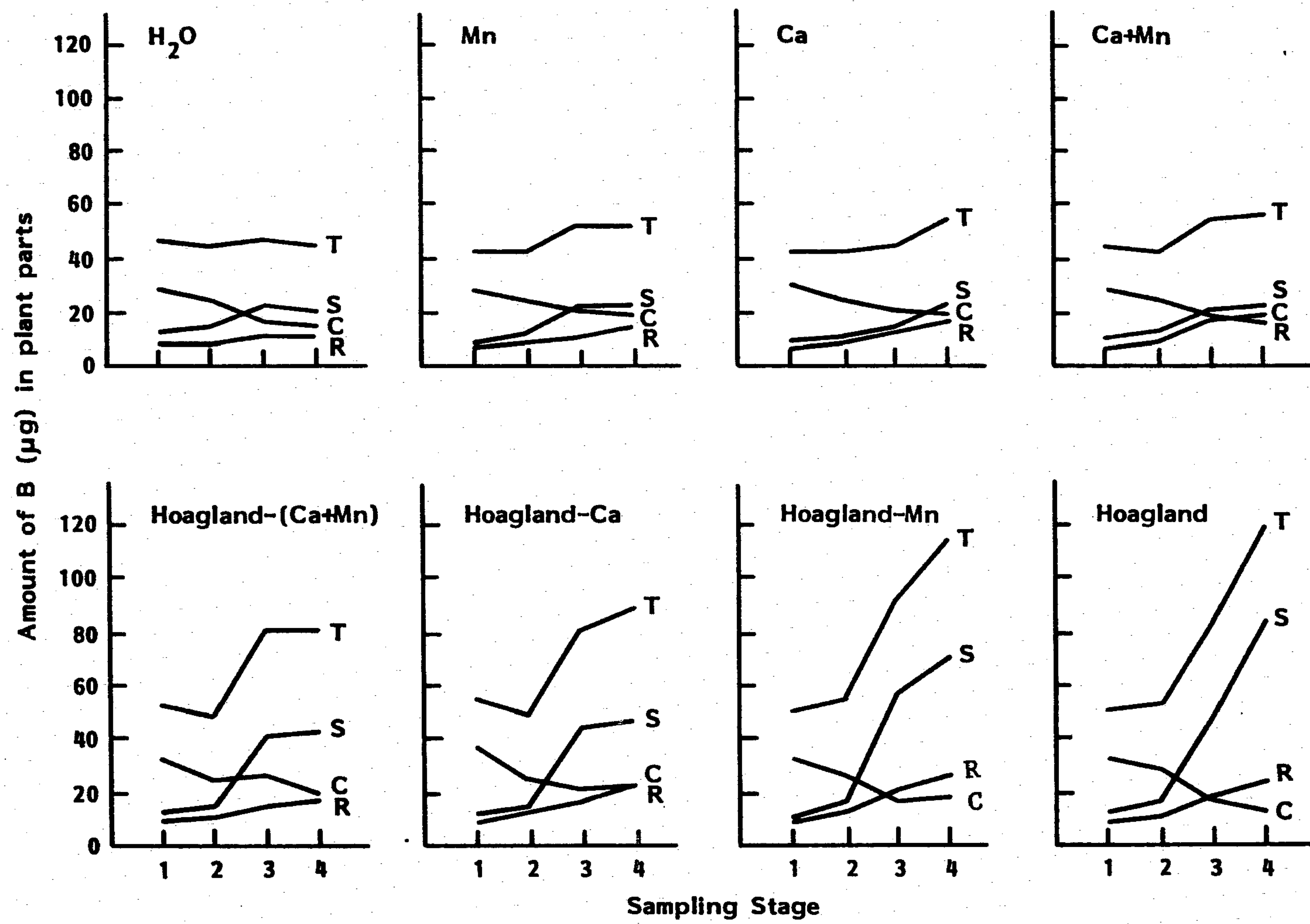

Figure 12. Variations in B content of whole plants (T), roots (R), shoots (S), and cotyledons (C) of soybean seedlings treated with different nutrient solutions

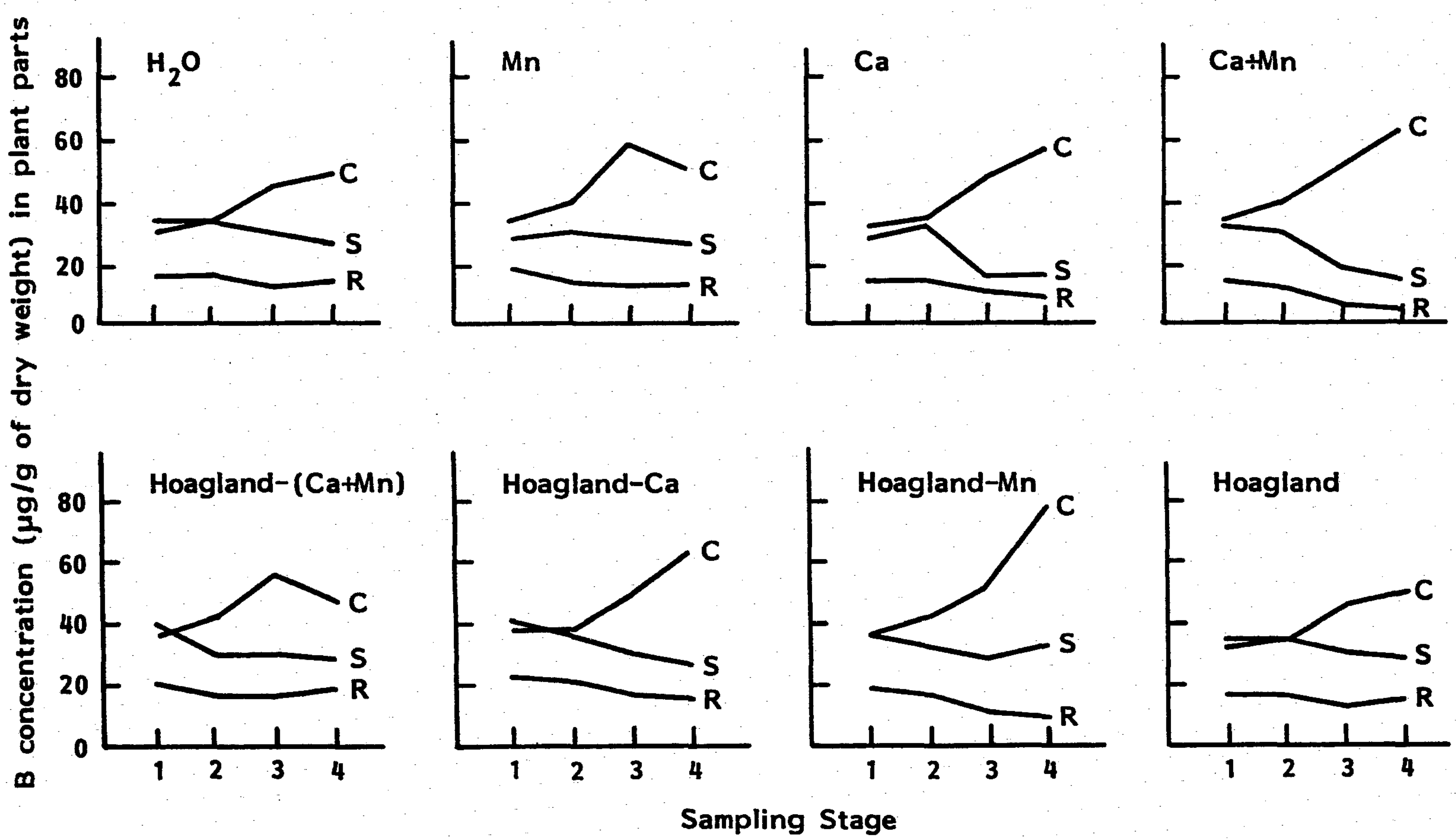

Figure 13. Variations in B concentration of roots (R), shoots (S), and cotyledons (C) of soybean seedlings treated with different nutrient solutions

Table 11. Analyses of variance of BRO, BSH, BCO, and TC -- Ca-Mn-Hoagland Experiment I

Source	DF	MS	F value	P>F
		BRO		
Total	95	35.94		
Rep	2	27.53	2.60	0.0820†
Stage	3	568.15	54.73	0.0001**
Trt	7	95.78	9.23	0.0001**
Ca	(1)	126.13	12.15	0.0009**
Mn	(1)	23.88	2.30	ns
Ca x Mn	(1)	22.42	2.17	ns
Hoag	(1)	452.05	43.55	0.0001**
Ca x Hoag	(1)	1.09	0.10	ns
Mn x Hoag	(1)	7.79	0.75	ns
Ca x Mn x Hoag	(1)	37.00	3.56	0.0637†
Trt x Stage	21	16.29	1.57	0.0874†
Error	62	10.38		
		BSH		
Total	95	407.37		
Rep	2	594.85	9.61	0.0002**
Stage	3	5268.70	85.10	0.0001**
Trt	7	1339.52	21.64	0.0001**
Ca	(1)	526.46	8.50	0.0049**
Mn	(1)	31.09	0.50	ns
Ca x Mn	(1)	1.25	0.02	ns
Hoag	(1)	7869.74	127.12	0.0001**
Ca x Hoag	(1)	926.36	14.96	0.0003**
Mn x Hoag	(1)	4.84	0.08	ns
Ca x Mn x Hoag	(1)	16.89	0.27	ns
Trt x Stage	21	404.25	6.53	0.0001**
Error	62	61.91		

Table 11. (Continued)

Source	DF	MS	F value	P>F
		BCO		
Total	95	52.27		
Rep	2	916.87	63.00	0.0001**
Stage	3	852.65	58.59	0.0001**
Trt	7	29.39	2.02	0.0662†
Ca	(1)	15.20	1.04	ns
Mn	(1)	0.31	0.02	ns
Ca x Mn	(1)	25.34	1.74	ns
Hoag	(1)	87.67	6.02	0.0169*
Ca x Hoag	(1)	66.70	4.58	0.0362*
Mn x Hoag	(1)	7.38	0.51	ns
Ca x Mn x Hoag	(1)	3.13	0.22	ns
Trt x Stage	21	19.80	1.36	ns
Error	62	14.55		
		TB		
Total	95	448.93		
Rep	2	2088.77	20.38	.0001**
Stage	3	3438.38	33.54	.0001**
Trt	7	1812.06	17.68	.0001**
Ca	(1)	996.47	9.72	.0028**
Mn	(1)	3143.61	30.67	.0001**
Ca x Mn	(1)	51.99	0.51	ns
Hoag	(1)	6216.71	60.64	.0001**
Ca x Hoag	(1)	1263.90	12.33	.0008**
Mn x Hoag	(1)	29.78	0.29	ns
Ca x Mn x Hoag	(1)	981.96	9.58	.0030**
Trt x Stage	21	434.04	4.23	.0001**
Error	62	102.51		

In Group I, the differences in TB due to different treatments were superficial. There was essentially no change in TB from one stage to the next. This was not totally unexpected because an extraneous source of B would have been required for any real increase in TB to occur -- a condition not met here. TB averaged 43 μg and 51 μg at Stages 1 and 4, respectively for the treatments in Group I. The marginal increases in TB due to the Mn, Ca, and Ca + Mn treatments compared to that for the H_2O treatment will be discussed later.

The total boron contents for Groups II and III (as described above) increased significantly in comparison to the amounts found in plants from Group I. TB obtained for Group II was intermediate relative to those for Groups I and III and was significantly different from both of them. The average TB for Group II of 53 μg at Stage 1, though slightly larger than the 50 μg for Group III, was different only from the 43 μg reported for Group I. There was an average of 84 μg at Stage 4, an increase of approximately 58 percent over the level at Stage 1.

There was a sharp increase in TB for treatments in Group III. TB averaged 50 μg and 116 μg at Stage 1 and 4, respectively. This was an average increase of about 132 percent more than the level at Stage 1. The increase in TB occurred in two phases. There was practically no change between Stages 1 and 2 followed by successive periods of very sharp increases (Stages 2 to 4).

The amount of B in different plant portions varied differently with the treatments used. The amount of B in the cotyledon decreased with stage but increased in roots and shoots. There was no difference among treatments with respect to the amount of B in the cotyledons. BCO averaged 30 μg at Stage 1 and varied from 27 μg for H_2O only to 35 μg for Hoagland - Ca. At Stage 4, the average B content of cotyledons was 16 μg; values for individual treatments varied from 11 μg with Hoagland to 21 μg when Hoagland - Ca was used. These results show that the average BCO decreased by about 13 μg between Stages 1 and 4. Therefore, only 43 percent of the B in the cotyledon at Stage 1 was removed or translocated by Stage 4. The results also show that using complete Hoagland Solution also enhanced the removal or translocation of B from the cotyledon.

On the basis of the amount of B in the roots of seedlings, there were two groups of treatments. These were Hoagland Solution treatments and Water Solution treatments. BRO averaged 6 μg at Stage 1 and 14 μg at Stage 4 for Water Solution treatments. Values for individual treatments varied from 5 to 7 μg (Stage 1 and from 9 to 18 μg (Stage 4). There were higher amounts of B in roots of plants grown using Hoagland Solution treatments. BRO averaged 8 μg and 21 μg at Stages 1 and 4, respectively. Values for individual treatments varied almost as much as in the previous group ranging from 7 to 8 μg and 15 to 24 μg at Stages 1 and 4, respectively.

There were three groups of treatments based on the amount of B in the shoots of seedlings: Group I -- H_2O, Mn, Ca, and Ca + Mn; Group II -- Hoagland - Ca and Hoagland - (Ca + Mn); and Group III -- Complete Hoagland and Hoagland - Mn. The change in B content for treatments in Group I was lower than that for Groups II and III. BSH averaged 9 μg at Stage 1 and 21 μg at Stage 4, an increase of about 133 percent for Group I.

In Group II, B content was only slightly higher at Stage 1 than the amount reported for Group I; but at Stage 4 the difference was very significant. BSH averaged 12 μg and 43 μg at Stages 1 and 4, respectively. This was an increase of 258 percent. Compared to Group 1, there was more than twice as much B in the shoots of plants in Group II.

The amount of B in the shoots of plants from Group III was the maximum obtained. There was little difference among treatment groups at Stage 1 but very large differences at Stage 4. The average amounts were 11 μg and 77 μg, respectively for Stages 1 and 4. There was approximately a 600 percent increase in BSH from Stage 1 to 4 for Group III. Comparing all three groups there is a 1:2:4 ratio of BSH for Groups I, II, and III, respectively at Stage 4.

Figure 13 shows changes in B concentration (μg/g dry weight) in different plant portions due to different nutrient solutions. Boron concentration increased in the cotyledon with advancing stage indicating that, relative to other components of the cotyledon, B was not removed very readily. Hence, as COWT decreased, B concentration tended to increase. In the roots and shoots, B concentration decreased with stage. Boron concentration was consistently higher in the shoots than in the roots. There was approximately a 2:1 ratio of BSH to BRO. The implications of these relationships are discussed later.

<u>Other micronutrients</u> Data on concentrations and amounts of Al, Cu, Fe, Na, and Zn for individual replications are presented in Tables B-1 and B-2, respectively, in the Appendix. The method used to study the

intercorrelations among nutrient content variables consisted of calculating the simple correlation coefficients between means of nutrient content variables in each plant portion studied. A correlation coefficient close to $r = \pm 1.00$ indicates the existance of a severe two-variable (in this case a two-nutrient) intercorrelation. The simple linear correlation coefficients between parts of nutrients in each plant portion higher than $r = \pm 0.60$ are given in Table 12 to show the degree of association between the amount of one nutrient and another in each of three portions of the plants.

The correlation analysis showed a high degree of intercorrelations ($r > \pm 0.69$ to 0.81) in the roots between Ca, Mg, and Mn, nutrients already investigated. It also indicated intercorrelations between these nutrients, as well as others already investigated, and most of the micronutrients listed earlier. In some cases, there was more than a two-nutrient intercorrelation since two nutrients showing high correlation were also correlated with a third nutrient. Further, Table 12 shows that B in the roots was highly intercorrelated with Ca and Mg ($r = .81$) and Mn ($r = .80$). B was also highly correlated with K ($r = .71$). There was a high correlation ($r = .81$) between Zn and P and between Zn and Cu ($r = .75$). A correlation coefficient ($r = .78$) was found between Na and Ca indicating a high degree of correlation. Al was highly correlated ($r = .71$) with Ca and very highly with Fe ($r = .94$) and Na ($r = .85$). The correlation analysis suggests a three-nutrient intercorrelation existing between Al, Na, and Ca, since the first two nutrients were highly corre-

Table 12. Simple linear correlations between means of nutrient content variables for each plant portion -- Ca-Mn-Hoagland Experiment I

	P	K	Ca	Mg	Mn	B	Na	Fe	Cu	Zn	Al
					ROOT $r > + 0.60$						
P	-	-	-		-	-	-	-	-	.81	-
K		-	-	.64	-	.72	-	-	-	-	-
Ca			-	.77	.81	.81	.78	.67	-	-	.71
Mg				-	.69	.81	-	-	-	-	-
Mn					-	.80	.65	.69	.62	-	.61
B						-	.71	.76	.61	-	.78
Na							-	.84	-	-	.85
Fe								-	-	-	.94
Cu									-	.75	-
Zn										-	-
Al											-
					SHOOT $r > + 0.60$						
P	-	.88	.76	.88	.93	.98	-	.86	.94	.96	.83
K		-	-	.99	.78	.90	.83	.68	.75	.78	.90
Ca			-	-	.71	.77	-	.76	.75	.74	-
Mg				-	.77	.91	.84	.72	.76	.80	.91
Mn					-	.91	-	.86	.92	.94	.76
B						-	.60	.86	.92	.93	.84
Na							-	-	-	-	.70
Fe								-	.90	.92	.79
Cu									-	.96	.73
Zn										-	.79
Al											-
					COTYLEDON $r > + 0.60$						
P	-	.76	-	.84	.83	.90	-	.95	.96	.97	-
K		-	-	.82	.78	.79	-	.66	.78	.78	-
Ca			-	-	-	-	-	-	-	-	-
Mg				-	.86	.93	-	.82	.82	.86	-
Mn					-	.89	-	.83	.85	.85	-
B						-	-	.90	.90	.93	-
Na							-	-	-	-	-
Fe								-	.94	.93	-
Cu									-	.97	-
Zn										-	-
Al											-

lated and each highly correlated with Ca. A three-nutrient intercorrelation between Al, Fe, and Ca is suggested for the same reason.

According to the concepts of correlation, variables that are highly correlated generally tend to show similarities in variations. Hence, for micronutrients that were highly correlated with any of the nutrients already discussed, we would expect them to have trends similar to those found for the nutrients with which they had high correlation. This eliminates the need for further analysis on the amount of each micronutrient in the roots because each one was highly correlated with at least one of the nutrients already investigated.

A similar situation was found in the shoots. Al was very highly correlated ($r = .91$) with Mg. The correlation coefficients for P with Cu and with Zn, respectively, were $r = .94$ and $r = .96$, indicating they were very highly correlated with P in the shoots. There were also high correlations between Fe and P ($r = .86$) and Na and Mg ($r = .84$). The analysis indicated the existence of intercorrelations involving more than two variables. One included P, B, and Cu; another involved P, B, and Zn; and another involved Mg, K, and Al. There were several other multiple intercorrelations. In summary, it can be said that in the shoots the effects of all minor nutrients (Al, Cu, Fe, Na, and Zn) were highly confounded with the nutrients already investigated (P, K, Ca, Mg, Mn, and B); and that the latter group of nutrients were all highly intercorrelated ($r = .71$ to $.98$).

In the cotyledons, there was high intercorrelations ($r = .76$ to $.93$) between the nutrients already investigated except Ca which had none $r > \pm .60$. Also, excluding Na and Al, all the micronutrients were very highly correlated ($r = .82$ to $.97$) with at least one of the nutrients already discussed.

B-Hoagland Experiment I

Results for total dry weights (TWT) and dry weights of roots (ROWT), shoots (SHWT), and cotyledons (COWT) for the four treatments (H_2O, B, Hoagland-B, and Hoagland) are presented in this section. Also, presented are results of the amounts and concentrations of P, K, Ca, Mg, Mn, and B present in each of three plant parts for seedlings grown with different nutrient solutions. Data for other nutrients (Al, Cu, Fe, Na, and Zn) were also collected and are presented in Table B-2 in the Appendix.

Dry weights

Average dry weights for the seedlings and for the roots, shoots, and cotyledons, as affected by each treatment at the four stages of sampling are presented in Table A-8 in the Appendix. Dry weights reported here are in mg. The experimental data showing dry weights for individual replications are presented in Table B-1, also in the Appendix. Table 13 summarizes the overall analysis of variance for the variables TWT, ROWT, SHWT, and COWT. The graphs in Figure 14 show the variations in dry weight as influenced by the different nutrient solutions used.

Table 13. Analyses of variance of ROWT, SHWT, COWT, and TWT -- B-Hoagland Experiment I

Source	DF	MS	F value	P>F
		ROWT		
Total	47	.82		
Rep	2	1.71	6.05	.0062**
Stage	3	4.63	16.39	.0001**
Trt	3	2.48	8.79	.0002**
B	(1)	.07	.26	ns
Hoag	(1)	6.53	23.12	.0001**
B x Hoag	(1)	.83	2.99	.0940†
Trt x Stage	9	.57	2.01	.0734†
Error	30	.28		
		SHWT		
Total	47	.71		
Rep	2	.37	2.45	ns
Stage	3	5.32	35.46	.0001**
Trt	3	1.95	12.98	.0001**
B	(1)	.12	.79	ns
Hoag	(1)	5.71	38.06	.0001**
B x Hoag	(1)	.01	.08	ns
Trt x Stage	9	.69	4.59	.0007**
Error	30	.15		
		COWT		
Total	47	.07		
Rep	2	.24	29.95	.0001**
Stage	3	.88	109.90	.0001**
Trt	3	.01	1.27	ns
B	(1)	.00	.04	ns
Hoag	(1)	.03	3.75	.0622†
B x Hoag	(1)	.00	.03	ns
Trt x Stage	9	.00	.58	ns
Error	30	.01		

Table 13. (Continued)

Source	DF	MS	F value	P>F
		TWT		
Total	47	2.43		
Rep	2	5.52	9.12	.0008**
Stage	3	12.75	21.07	.0001**
Trt	3	8.95	14.79	.0001**
B	(1)	0.00	0.01	ns
Hoag	(1)	26.21	43.33	.0001**
B x Hoag	(1)	0.63	1.04	ns
Trt x Stage	9	2.22	3.68	.0034**
Error	30	0.60		

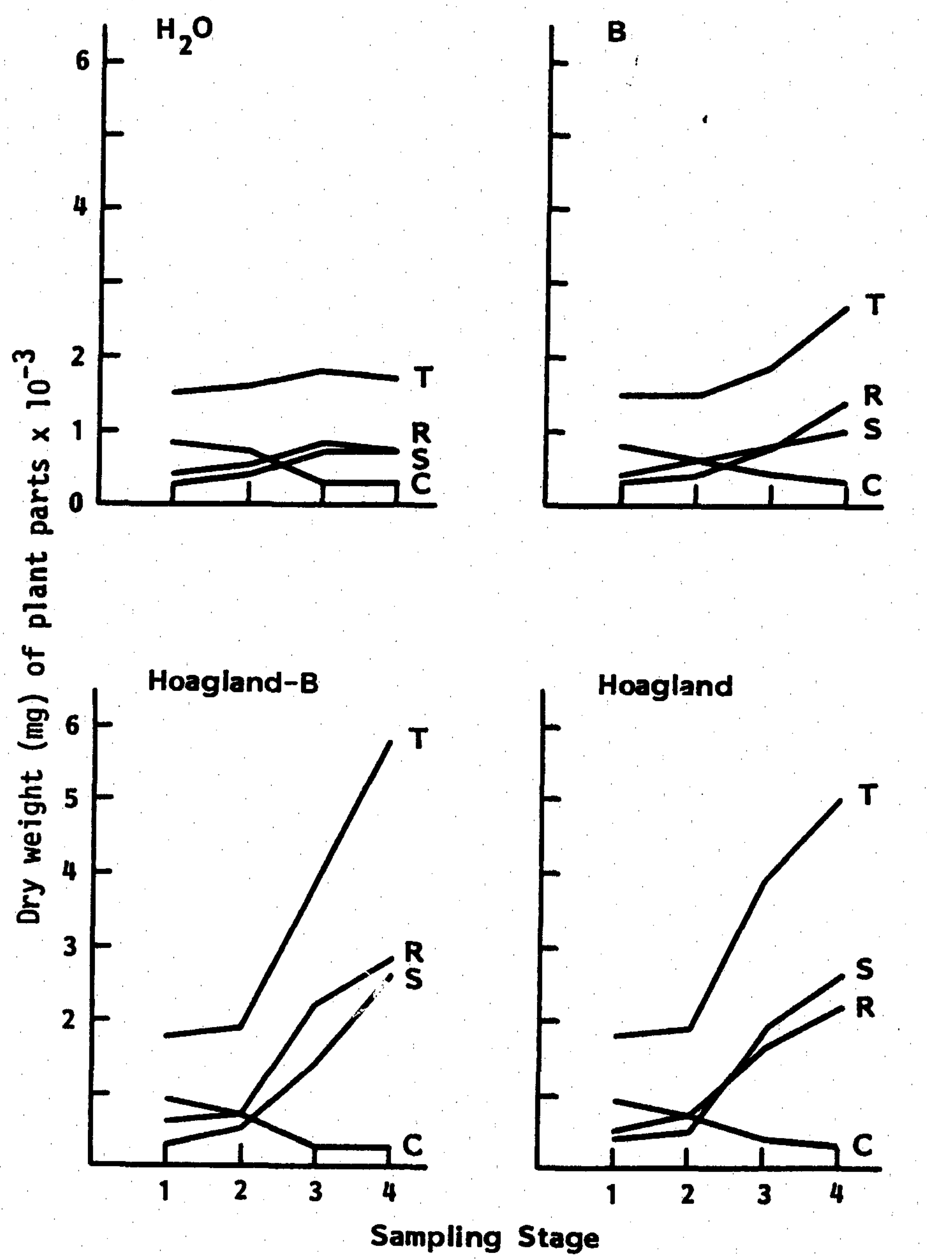

Figure 14. Variations in total dry weights (T), and dry weights of roots (R), shoots (S), and cotyledons (C) of soybean seedlings treated with different nutrient solutions

Total dry weights obtained were similar for treatments of similar composition but different among treatment groups. The treatment groups were Hoagland Solution and Water Solution groups. There was little change in total dry weights for Water treatments. When only H_2O was used TWT was practically unchanged. But when B was used, there were small increases in TWT at Stages 3 and 4 due largely to increases in the root dry weights which occurred at these stages. These increases, however, were too small to be of practical significance. Total dry weight for the two treatments averaged approximately 1770 mg over all times of sampling. The average TWT increased slightly with successive stages of sampling and ranged from 1520 mg at Stage 1 to 2195 mg at Stage 4.

The total dry weights of plants increased significantly when Hoagland Solution treatments were used. The Hoagland treatments used in this experiment were Hoagland-B and Complete Hoagland Solution. The increases in TWT occurred mainly during the last two sampling periods. There was slightly more TWT when Hoagland-B was used than was obtained with Complete Hoagland. This difference was due to an increase in root weight with the Hoagland-B treatment. TWT averaged about 1700 mg at Stage 1 for both treatments. There was little change in TWT at Stage 2 after which it increased very sharply -- linearly throughout for Hoagland-B and with a slight tapering off at Stage 3 for Hoagland. At Stage 4 there were approximately 5800 mg (Hoagland-B) and 5000 mg (Hoagland) TWT values which were not significantly different.

Cotyledon dry weights declined with stage and were not affected by the treatments. COWT averaged 900 mg at Stage 1 and about 300 mg at Stage 4. Hence, for all treatments, nearly two-thirds of the COWT at Stage 1 was lost by the time of final sampling. These results were consistent with what was expected. Overall, treatment effect (Table 13) was non-significant, despite the significant Hoag main effect (at 0.10 level).

There were differences in root dry weights obtained with different treatments -- differences that were similar for treatments of similar composition. The dry weights of roots due to Hoagland treatments increased significantly in comparison to those for Water treatments. Among Hoagland treatments, ROWT obtained with the Hoagland-B treatment was consistently higher than that for the Complete Hoagland treatment. It averaged 1603 mg over all times of sampling and varied from 600 mg at Stage 1 to 2840 mg at Stage 4. When Hoagland was used, ROWT averaged 1260 mg over all stages and increased from 450 mg at Stage 1 to 2180 mg at Stage 4. An F value of 8.79 for the overall treatment effect on root dry weight was highly significant (Table 13). The main effect of B on ROWT was not significant. There was an F value of 23.12 for Hoag main affect which was highly significant (0.01 level).

Shoot dry weights obtained with Hoagland treatments were about equal for both Hoagland treatments and were significantly different from those for Water treatments. There was an average of 1260 mg for SHWT obtained with Hoagland and Hoagland-B for the four stages of sampling. The average SHWT for both treatments at Stages 1 and 4, respectively, were 325 mg and

2605 mg. The statistics in Table 13 show that overall, Stage, Trt, and Hoag effects were highly significant (0.01 level) but B effect was non-significant.

Mineral nutrients

Phosphorus Average P content of the seedlings (TP) and of the roots (PRO), shoots (PSH), and the cotyledons (PCO) given in Table A-9 in the Appendix are shown graphically in Figure 15 for each treatment. The values are in mg. The experimental data showing P contents for individual replications are presented in Table B-2, also in the Appendix. Figure 16 shows the variations in P concentrations in each plant part. The analyses of variance for the variables TP, PRO, PSH, and PCO are summarized in Table 14.

The total phosphorus content of the seedlings or TP was defined as the sum of P content found in the three plant parts studied. TP averaged 9 mg over all stages for H_2O, B alone, and Hoagland-B treatments and 11 mg for the Complete Hoagland treatment. There were minor variations in TP from stage to stage for the first three treatments and wide fluctuations with Complete Hoagland. TP showed a tendency to decline with increasing stage when H_2O and B were used. When Hoagland-B was used, TP fluctuated between 8 and 9 mg (Stages 1 to 3) and then increased to 11 mg at Stage 4. When Complete Hoagland was used, TP declined from Stage 1 to 2 and then increased sharply to 16 mg at Stage 4. Nevertheless, there was no difference among TP obtained with different treatments. Table 14 shows that treatment effect on TP was nonsignificant. However, the model used had a low R^2 value (0.51) and, hence, could not adequately account for the variations that occurred in total phosphorus in the plants.

The treatments used had a differential response in terms of the proportion of total P found in different portions of the plants. The relative amount of P found in the cotyledons consistently declined with stage. It changed from an average of 5 mg at Stage 1 to about 1 mg at Stage 4, a decline of 80 percent. The loss in P from the cotyledons was weakly affected by the treatments. The overall treatment effect was significant only at the 0.10 level and this was due largely to the Hoag main effect which was significant at the 0.05 level (Table 14).

The amount of P in the roots changed only slightly overall and was not affected by the treatments. PRO averaged 2 mg at Stage 1 and 4 mg at Stage 4 for all four treatments. Table 14 shows that treatment effect was nonsignificant, despite the significant Hoag effect (0.10 level).

Phosphorus content of the shoots (PSH) varied only slightly due to Water treatments but increased significantly when Hoagland treatments were used. PSH averaged 2 mg at Stage 1 and 4 mg at Stage 4 when Water treatments were used. When Hoagland treatments were used, the amount of P in the shoots averaged 2 mg and 9 mg at Stages 1 and 4, respectively. Table 14 shows that, overall, treatment effect was significant (0.05 level) due mainly to Hoag main effect which was highly significant (0.01 level). B effect was nonsignificant.

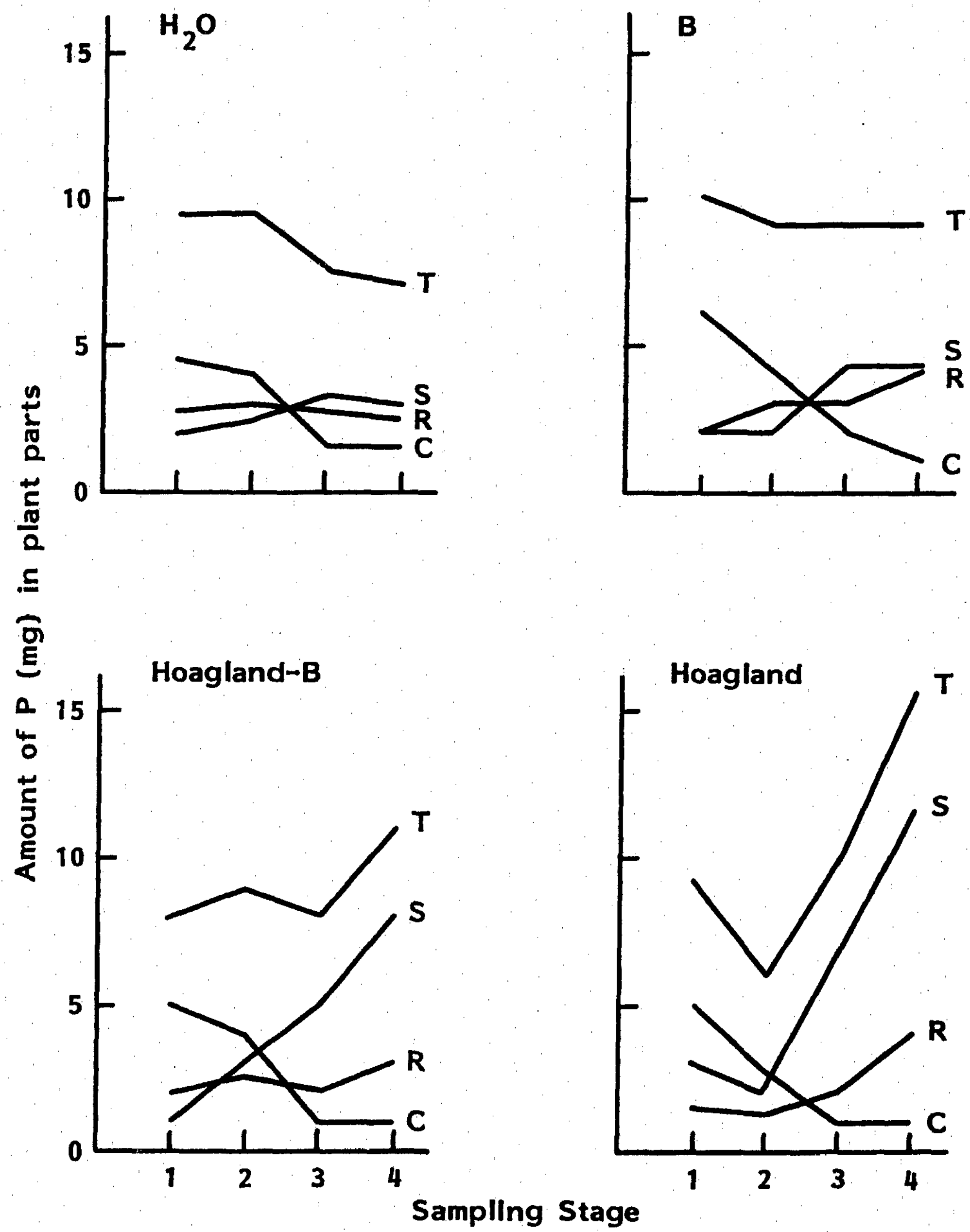

Figure 15. Variations in P content of whole plants (T), roots (R), shoots (S), and cotyledons (C) of soybean seedlings treated with different nutrient solutions

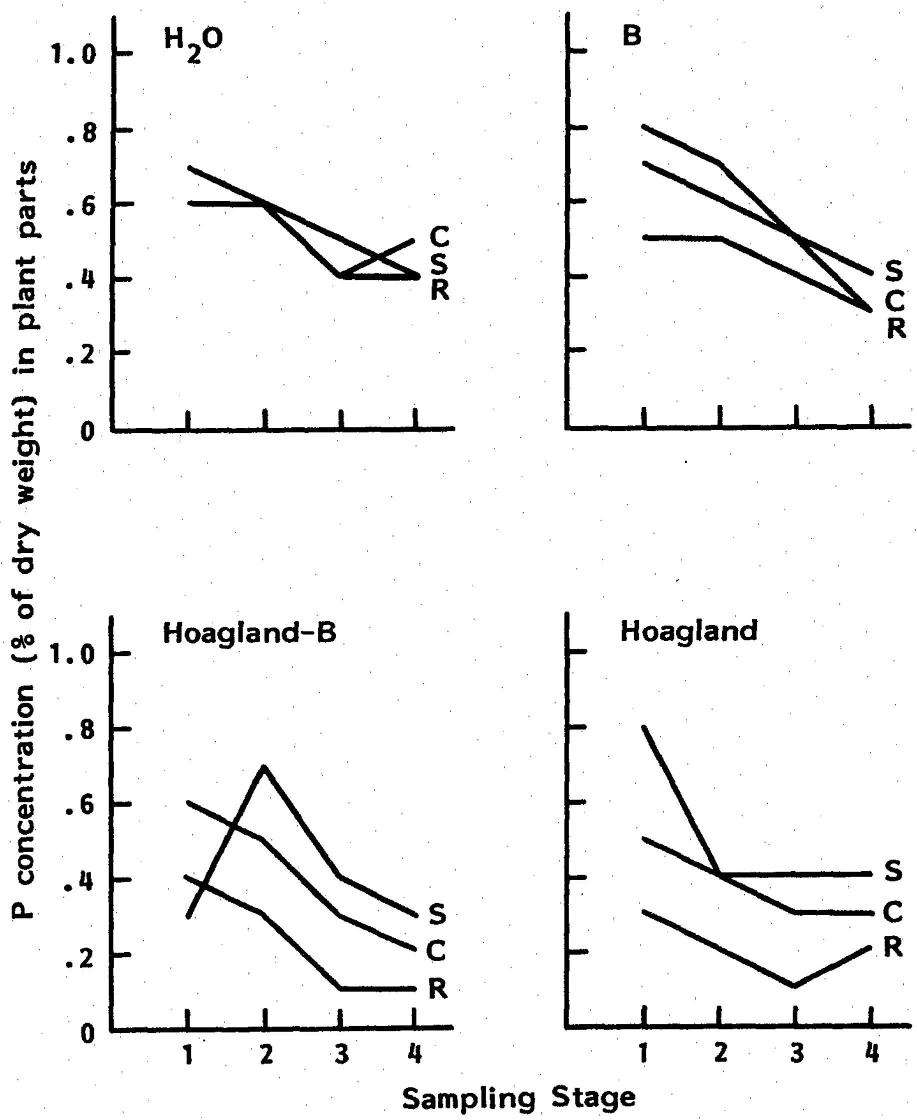

Figure 16. Variations in P concentration of roots (R), shoots (S), and cotyledons (C) of soybean seedlings treated with different nutrient solutions

Table 14. Analyses of variance of PRO, PSH, PCO, and TP -- B-Hoagland Experiment I

Source	DF	MS	F value	P>F
		PRO		
Total	47	1.52		
Rep	2	5.34	4.22	0.0242*
Stage	3	2.15	1.70	ns
Trt	3	1.84	1.46	ns
B	(1)	0.00	0.00	ns
Hoag	(1)	4.92	3.89	0.0579†
B x Hoag	(1)	0.61	0.48	ns
Trt x Stage	9	1.20	0.95	ns
Error	30	1.26		
		PSH		
Total	47	12.33		
Rep	2	9.49	1.43	ns
Stage	3	58.93	8.86	0.0002**
Trt	3	25.41	3.82	0.0198*
B	(1)	10.28	1.55	ns
Hoag	(1)	62.72	9.43	0.0045**
B x Hoag	(1)	3.24	0.49	ns
Trt x Stage	9	11.99	1.80	ns
Error	30	6.65		
		PCO		
Total	47	3.48		
Rep	2	6.52	23.84	0.0001**
Stage	3	45.45	166.22	0.0001**
Trt	3	0.71	2.58	0.0718†
B	(1)	0.02	0.06	ns
Hoag	(1)	1.97	7.21	0.0117*
B x Hoag	(1)	0.13	0.49	ns
Trt x Stage	9	0.41	1.51	ns
Error	30	0.27		

Table 14. (Continued)

Source	DF	MS	F value	P>F
		TP		
Total	47	15.19		
Rep	2	60.47	5.23	.0113*
Stage	3	13.60	1.18	ns
Trt	3	9.46	0.82	ns
B	(1)	9.47	0.82	ns
Hoag	(1)	18.47	1.60	ns
B x Hoag	(1)	0.43	0.04	ns
Trt x Stage	9	19.65	1.70	ns
Error	30	11.56		

Figure 16 shows the variations in P concentrations (expressed as percentage of dry weights) in the various plant parts due to different nutrient solutions. Data on P concentration for individual replications are presented in Table B-1 in the Appendix. The graphs in Figure 16 show that P concentration decreased with successive stages of sampling for all plant parts. In general, there was less variability in percent P both among plant parts and over the times of sampling with Water treatments than with Hoagland treatments.

When H_2O was used, percent P in the cotyledons changed from 0.7 percent at Stage 1 to 0.5 percent at Stage 4. There was an increase of 0.1 percent between Stages 3 and 4. Where B alone was used PCO changed from 0.7 percent to 0.3 percent at Stage 1 and 4, respectively. The initial P concentrations were slightly lower with Hoagland treatments averaging 0.6 percent compared to 0.7 percent with Water treatments. P concentrations in the cotyledons declined to 0.2 percent and 0.3 percent at Stage 4 with Hoagland-B and Complete Hoagland treatments, respectively.

In general, P concentration was consistenly lower in the roots than in other portions of the plants for all treatments. It averaged slightly higher for Water treatments than for Hoagland treatments. The average PRO values due to Water treatments were 0.6 percent and 0.4 percent at Stages 1 and 4, respectively. For Hoagland treatments, they averaged 0.5 percent and 0.2 percent, respectively, at Stages 1 and 4.

Phosphorus concentration in the shoots fluctuated more widely than in other parts especially with the Hoagland treatments. It was generally higher than the levels found in the other plant parts. For Water treatments, PSH concentration averaged 0.6 percent at Stage 1 and 0.4 percent at Stage 4. There were large differences in PSH concentration due to the Hoagland treatments, particularly at Stage 1. When Hoagland-B was used, there was 0.3 percent PSH compared to 0.8 percent PSH when Hoagland was used. At Stage 4, there were 0.3 and 0.4 percent PSH due to Hoagland-B and Hoagland, respectively. An explanation of these relationships will be done in the Discussion Section.

Potassium The average K contents (in mg) in the whole seedling (TK) and in the roots (KRO), in shoots (KSH), and in cotyledons (KCO) due to different nutrient solutions are presented in Table A-10 in the Appendix. Figure 17 is a graphic representation of these means. Potassium content for each replication at the four times of sampling as influenced by the different nutrient solutions are given in Table B-2 in the Appendix. The overall analyses of variance for the variables TK, KRO, KSH, and KCO are summarized in Table 15. The average variations in K concentrations in different plant portions, as influenced by the different nutrient solutions, are shown in Figure 18. Table B-1 in the Appendix shows K concentrations for individual replications.

The amounts of TK in the seedlings were similar for Water treatments as a group, and for Hoagland treatments, again as a group, but different among groups. There was practically no change in TK for Water treatments (H_2O and B). TK averaged approximately 25 mg over times of sampling and values ranged from 21 to 30 mg. In general, there were slightly higher amounts of TK during the earlier stages and lesser amounts at the latter stages. However, these changes were very minimal and therefore of little practical significance. When the Hoagland treatments were used, there were significantly higher amounts of TK in the seedlings. TK increased from 29 mg (Stage 1) to 85 mg (Stage 4) when Hoagland-B was used. This was approximately a threefold increase in TK. When Complete Hoagland was used, TK changed from 46 mg to 128 mg at Stages 1 and 4, respectively. Again there was a threefold increase in TK from Stage 1 to Stage 4. The amount of TK due to Hoagland-B at Stages 1 and 4 was respectively 61 percent and 66 percent, of those found in plants grown with Complete Hoagland at corresponding stages. Table 15 shows that the effects of treatment Hoag and B on TK were all highly significant (0.01 level).

The amount of K in various plant portions varied with the treatments almost in accordance with the variations reported for TK above. The proportion of TK found in different parts varied with each treatment. Potassium content in the cotyledons declined with stage, as was expected, and increased in roots and shoots. These similarities and differences are presented below in more detail.

The amount of potassium in the cotyledons (KCO) declined consistently with stage for all four treatments. There were slightly more KCO at Stage 1 due to B; Hoagland-B, and Hoagland as compared to the H_2O treatment. These amounts, respectively, were 1 mg (8 percent); 3 mg (23 percent); and 7 mg (54 percent) more than the 13 mg found in plants treated with only H_2O. For samples taken at Stage 4, KCO was 3 mg for the H_2O

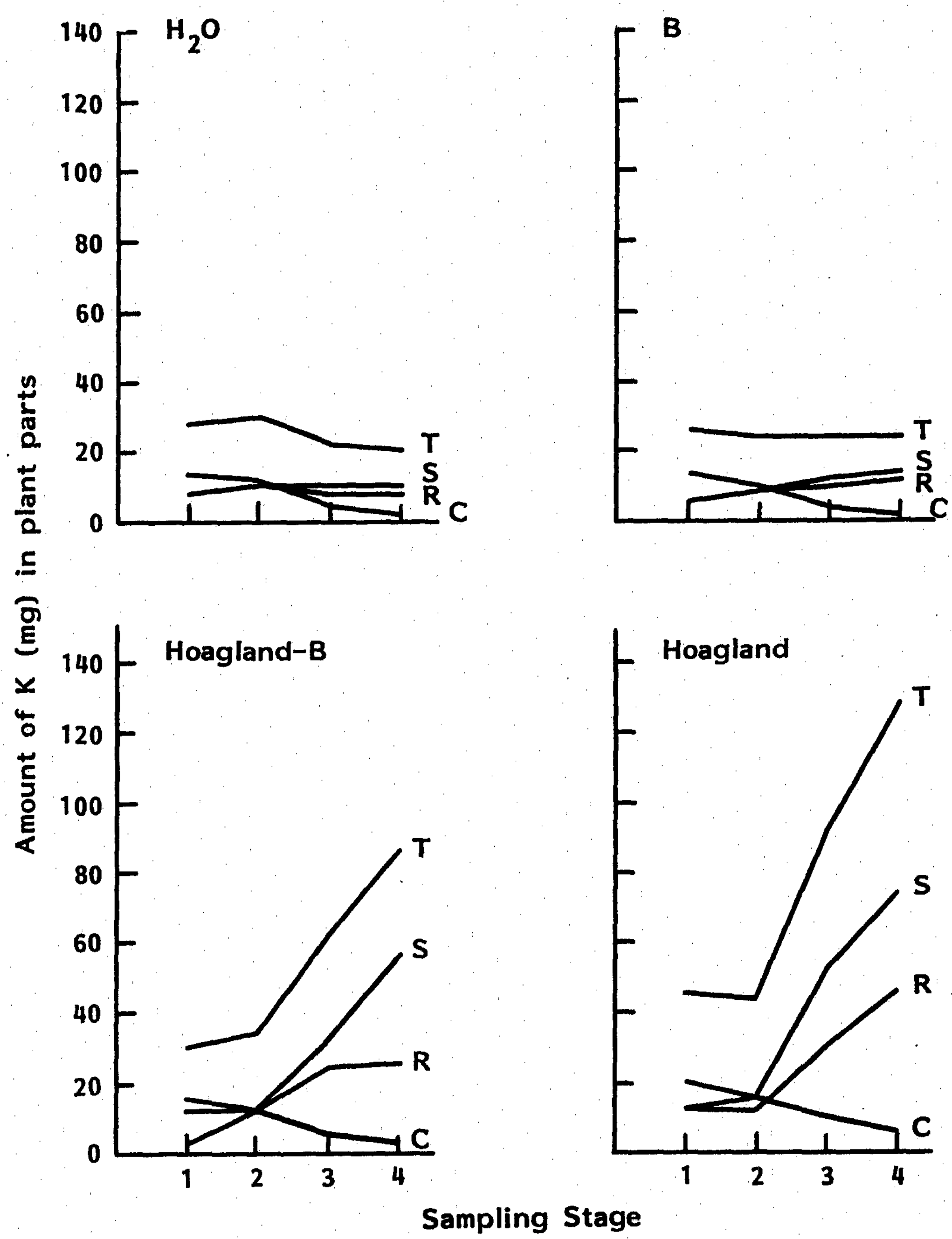

Figure 17. Variations in K content of whole plants (T), roots (R), shoots (S), and cotyledons (C) of soybean seedlings treated with different nutrient solutions

Table 15. Analyses of variance of KRO, KSH, KCO, and TK -- B-Hoagland Experiment I

Source	DF	MS	F value	P>F
		KRO		
Total	47	134.59		
Rep	2	22.24	0.74	ns
Stage	3	498.04	16.49	0.0001**
Trt	3	808.50	27.04	0.0001**
B	(1)	182.56	6.04	0.0200*
Hoag	(1)	2123.04	70.27	0.0001**
B x Hoag	(1)	144.90	4.80	0.0364*
Trt x Stage	9	158.92	5.26	0.0003**
Error	30	30.21		
		KSH		
Total	47	497.55		
Rep	2	141.10	2.15	ns
Stage	3	2469.45	37.67	0.0001**
Trt	3	2480.60	37.84	0.0001**
B	(1)	535.27	8.16	0.0077**
Hoag	(1)	6325.54	96.95	0.0001**
B x Hoag	(1)	549.88	8.39	0.0070**
Trt x Stage	9	646.16	9.86	0.0001**
Error	30	65.56		
		KCO		
Total	47	36.40		
Rep	2	76.83	24.83	0.0001**
Stage	3	382.14	120.94	0.0001**
Trt	3	98.95	31.32	0.0001**
B	(1)	33.35	10.55	0.0029**
Hoag	(1)	180.33	57.07	0.0001**
B x Hoag	(1)	83.16	26.32	0.0001**
Trt x Stage	9	2.10	0.66	ns
Error	30	3.16		

Table 15. (Continued)

Source	DF	MS	F value	P>F
		TK		
Total	47	1015.82		
Rep	2	639.04	7.18	.0028**
Stage	3	2838.85	31.89	.0001**
Trt	3	7725.12	88.77	.0001**
B	(1)	1799.60	20.21	.0001**
Hoag	(1)	19386.08	217.74	.0001**
B x Hoag	(1)	1989.70	22.35	.0001**
Trt x Stage	9	1344.75	15.10	.0001**
Error	30	89.03		

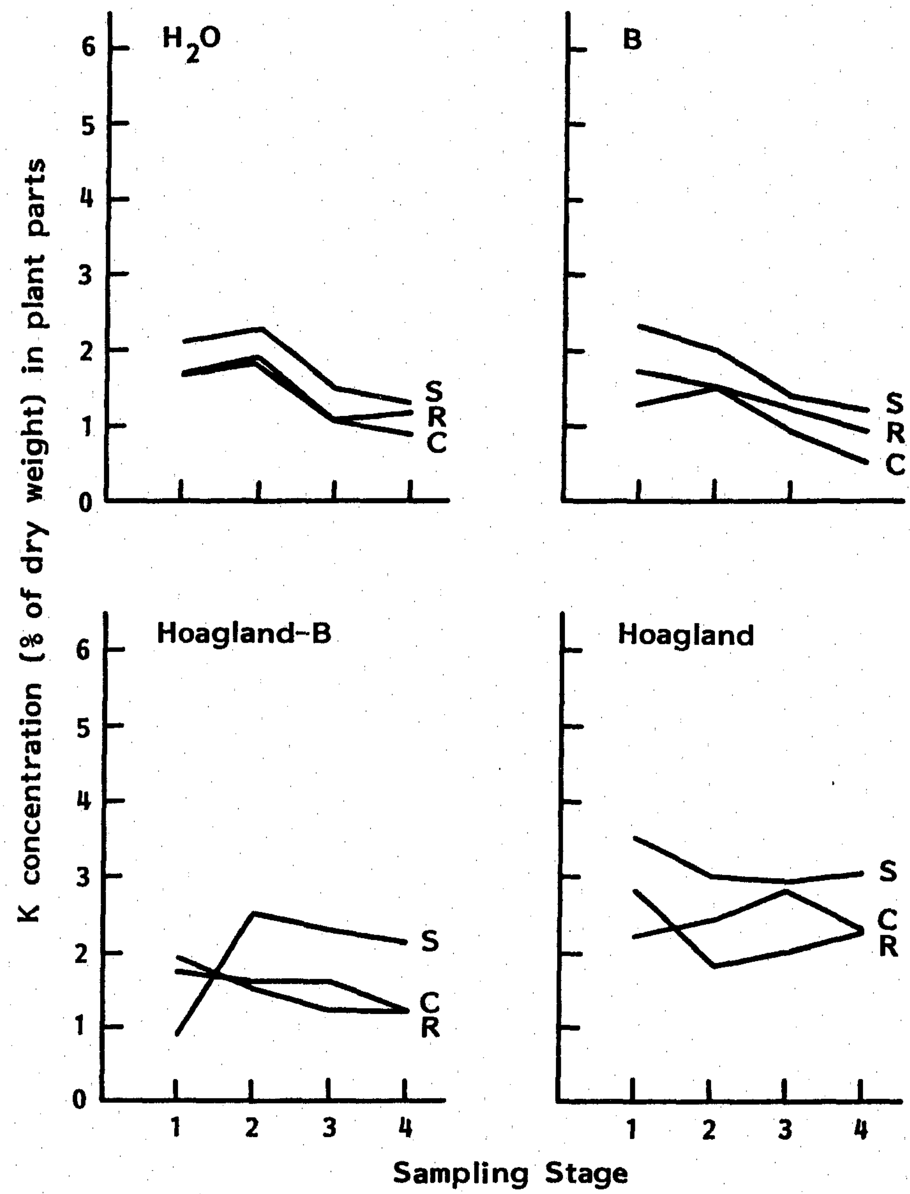

Figure 18. Variations in K concentration of roots (R), shoots (SH), and cotyledons (C) of soybean seedlings treated with different nutrient solutions

treatment; 1 mg for B alone; 4 mg for Hoagland-B; and 7 mg for Hoagland. These values were 23 percent, 7 percent, 25 percent, and 35 percent of the KCO values at Stage 1, respectively, for the treatments listed above. These results show that notwithstanding the effects of different treatments on K content of the cotyledons, K was very readily translocated from the cotyledons throughout the sampling period. As shown earlier, between 65 and 92 percent of the KCO at Stage 1 was translocated by Stage 4. Table 15 shows that treatment effect had an F value of 31.32 which was highly significant (0.01 level). The B and Hoag effects were also highly significant.

The amount of K in the roots increased with stage for all treatments but there were marked differences between treatments of different composition. K contents in the roots were low when Water treatments were used. There was practically no difference between KRO for the H_2O and B treatments. KRO averaged 7 mg at Stage 1 and increased to 10 mg at Stage 4. There were significant increases in the amount of K found in the roots of plants treated with the Hoagland treatments as compared to those mentioned above. On the average, there were nearly 1:2 and 1:4 ratios of KRO at Stages 1 and 4, respectively for Water vs Hoagland treatments. The amounts of KRO due to Hoagland-B at Stages 1 and 4 were 11 mg and 26 mg, respectively. When Hoagland was used, there were 13 mg (Stage 1) and 46 mg (Stage 4). There was nearly twice as much KRO due to Hoagland compared to Hoagland-B at Stage 4. Table 15 shows that the overall effects of treatment and Hoag were highly significant (0.01 level) and that B effect was significant at the 0.05 level.

Potassium content in the shoots (KSH) increased with stage for all treatments but the rates and amounts of change were different for each treatment. There were similarities in the trends shown for treatments of similar composition: KSH was low for Water treatments and high for Hoagland treatments.

There was no real difference in KSH due to the H_2O and B treatments. KSH averaged 7 mg at Stage 1 and 11 mg at Stage 4. When Hoagland-B and Hoagland were used, there were large differences in KSH obtained and they, as a group, differed from Water treatments substantially. KSH changed from 2 mg at Stage 1 to 55 mg at Stage 4 when Hoagland-B was used. When Hoagland was used, there were 13 mg and 75 mg KRO, respectively, at Stages 1 and 4. Hence, KSH averaged 8 mg and 65 mg at Stages 1 and 4 with Hoagland treatments, as a group. Ratios of 1:1 and 1:6 were found at Stages 1 and 4, respectively, for KSH due to Water vs Hoagland treatments. Table 15 shows that the effects of treatment, B, and Hoag on KSH were highly significant.

Figure 18 shows the variations in K concentrations (as percent of dry weights) in each plant portion at each time of sampling due to different nutrient solutions. Table B-1 in the Appendix presents K concentrations for individual replications. Two different trends are shown by the graphs in Figure 18. Potassium concentrations due to Water treatments declined with stage in all three plant portions. When Hoagland treatments were used, K concentrations seemed to hold steady or decline only slightly. The two exceptions were a sharp increase in percent KSH (Stages 1-2) due to Hoagland-B and a sharp decline in percent KRO (Stages 1-2) due to Hoagland.

Graphs for Water treatments showed that K concentrations in the three plant portions were consistently in the order shoots > roots > cotyledons. Potassium concentrations averaged 2.20 percent and 1.25 percent at Stages 1 and 4, respectively in the shoots; 1.50 percent and 1.05 percent in the roots; and 0.85 percent and 0.70 percent in the cotyledons. Graphs for Hoagland treatments showed that, disregarding Stage 1 (for reasons cited earlier), K concentrations in plant parts were consistently in the order shoots > cotyledons > roots. On this basis, the average K concentrations at Stages 2 and 4, respectively, were 2.75 percent and 2.55 percent in the shoots; 2.00 percent and 1.75 percent in the cotyledons; and 1.65 percent and 1.70 percent in the roots. There was a small increase in percent K in the roots at Stage 4 but the increase was too small to be considered trend-setting.

Calcium The average Ca content (in mg) in the whole seedlings (TCa), in roots (CaRO), in shoots (CaSH), and in cotyledons (CaCO) at each stage of sampling as influenced by different nutrient solutions are presented in Table A-11 in the Appendix. The values are presented graphically in Figure 19. Calcium content data for individual replications are presented in Table B-2 in the Appendix. Figure 20 shows the average variations in Ca concentrations (expressed as percent of dry weights) in different plant portions as influenced by the nutrient solutions used. Calcium concentrations as determined in samples taken from the plant parts for individual replications are presented in Table B-1. The analyses of variance for the Ca content variables are summarized in Table 16.

Figure 19 shows very sharp differences in the total amount of Ca found in plants grown with Water treatments vs those grown with Hoagland treatments. In Water treatments, there was essentially no change in TCa with stage. TCa averaged about 3.45 mg over all stages and ranged from 2.9 to 4.3 mg for both treatments. The amount of TCa in plants due to Hoagland treatments increased significantly when compared to that found when Water treatments were used. There was little difference in TCa at Stage 1 among Water and Hoagland treatments but the differences increased substantially with stage. TCa changed from 4.3 mg at Stage 1 to 39.1 mg at Stage 4 when Hoagland-B was used. The change in TCa due to Complete Hoagland was from 6.0 mg to 32.2 mg at Stages 1 and 4, respectively. There was a sharp abatement at Stage 3 in the rate of increase in TCa with the Complete Solution which resulted from changes in the rate of Ca accumulation in the shoots. This will be dealt with later. Table 16 shows an F value of 55.52 for treatment effect which was highly significant at the 0.01 level. This was due almost exclusively to the highly significant Hoag effect. The B effect was nonsignificant.

The amounts of Ca in different plant portions were influenced differentially by the treatments. In general, there were increases in Ca contents of roots and shoots for all treatments; and essentially no change in the amount of Ca in cotyledons with Hoagland treatments and a decrease in CaCO with Water treatments. There were very large differences among

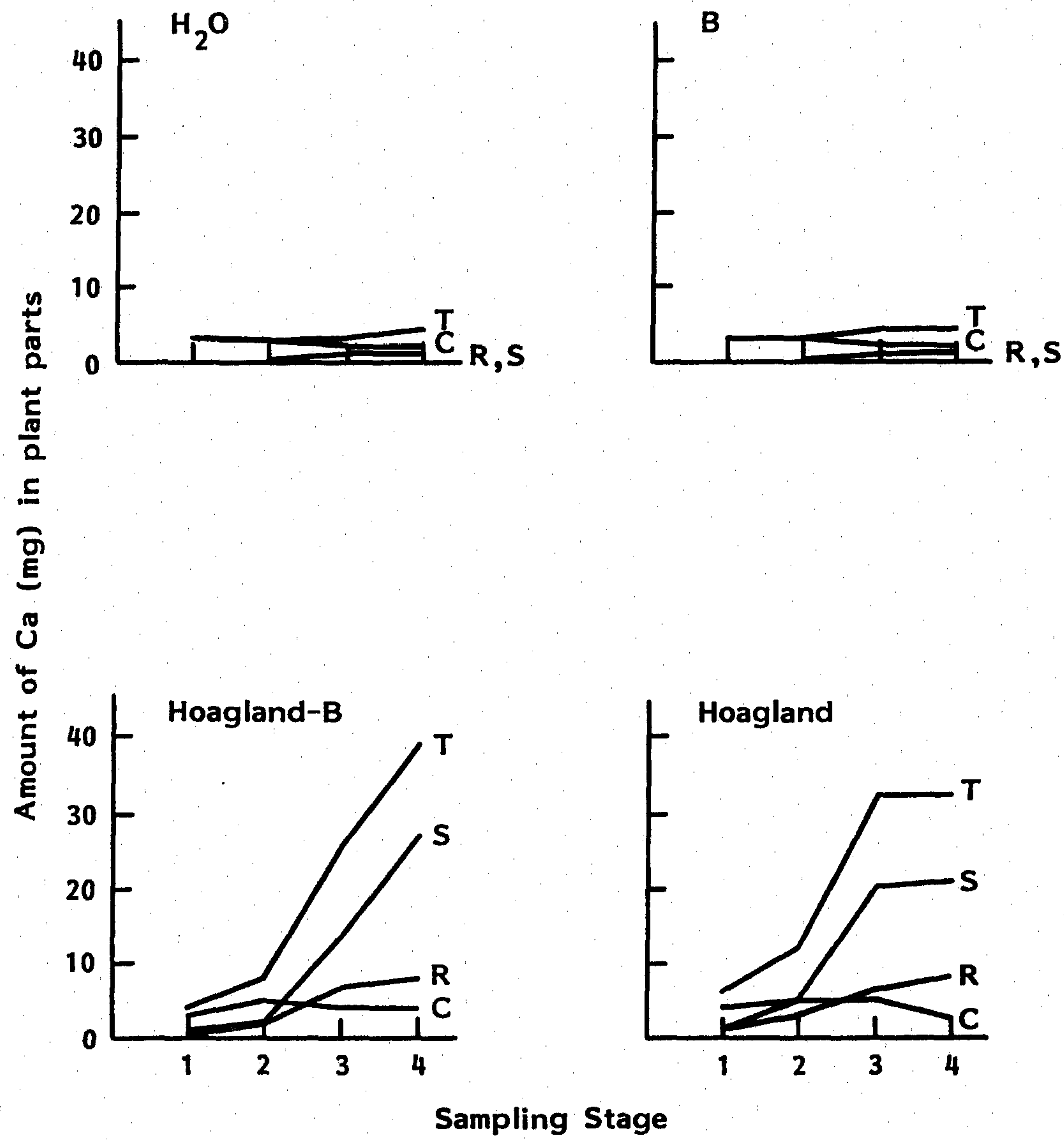

Figure 19. Variations in Ca content of whole plants (T), roots (R), shoots (S), and cotyledons (C) of soybean seedlings treated with different nutrient solutions

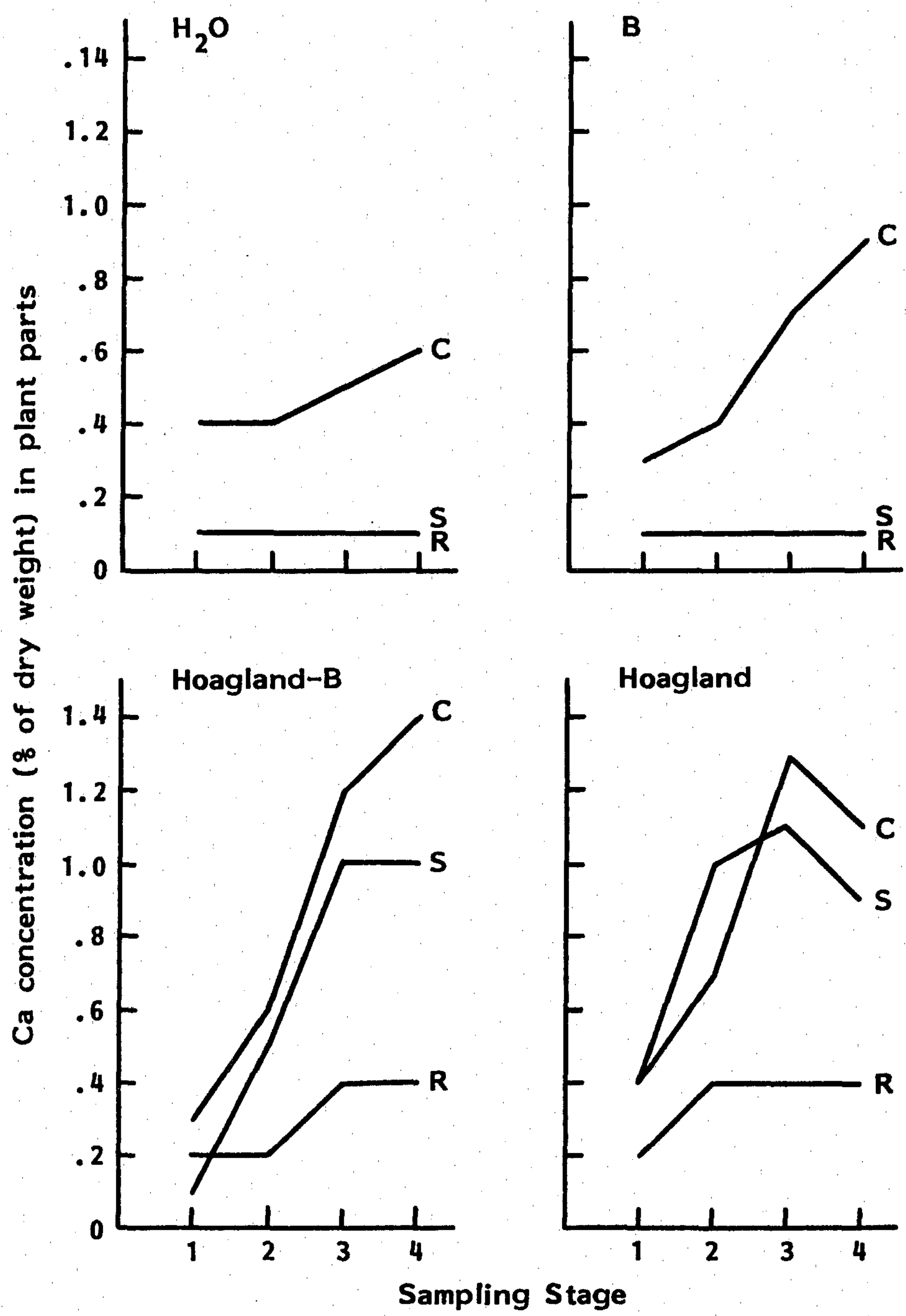

Figure 20. Variations in Ca concentration of roots (R), shoots (S), and cotyledons (C) of soybean seedlings treated with different nutrient solutions

Table 16. Analyses of variance of CaRO, CaSH, CaCO, and TCa -- B-Hoagland Experiment I

Source	DF	MS	F value	P>F
		CaRO		
Total	47	9.56		
Rep	2	0.80	0.77	ns
Stage	3	43.70	42.19	0.0001**
Trt	3	62.48	63.31	0.0001**
B	(1)	0.00	0.00	ns
Hoag	(1)	187.44	180.93	0.0001**
B x Hoag	(1)	0.00	0.00	ns
Trt x Stage	9	10.88	10.50	0.0001**
Error	30	1.04		
		CaSH		
Total	47	88.96		
Rep	2	22.30	1.58	ns
Stage	3	381.48	27.06	0.0001**
Trt	3	476.65	33.81	0.0001**
B	(1)	3.25	0.23	ns
Hoag	(1)	1424.00	100.99	0.0001**
B x Hoag	(1)	2.69	0.19	ns
Trt x Stage	9	379.74	8.98	0.0001**
Error	30	14.10		
		CaCO		
Total	47	1.67		
Rep	2	6.88	11.24	0.0002**
Stage	3	1.50	2.45	0.0827†
Trt	3	10.92	17.85	0.0001**
B	(1)	0.58	0.94	ns
Hoag	(1)	32.08	52.43	0.0001**
B x Hoag	(1)	0.11	0.17	ns
Trt x Stage	9	1.03	1.66	ns
Error	30	0.61		

Table 16. (Continued)

Source	DF	MS	F value	P>F
		TCa		
Total	47	168.18		
Rep	2	53.06	2.70	.0832†
Stage	3	651.53	33.21	.0001**
Trt	3	1089.55	55.52	.0001**
B	(1)	6.65	0.34	ns
Hoag	(1)	3259.31	166.14	.0001**
B x Hoag	(1)	1.68	0.09	ns
Trt x Stage	9	220.82	11.26	.0001**
Error	30	19.62		

Ca contents due to Water treatments vs those due to Hoagland treatments in all plant portions studied. These differences were consistent with differences in nutrient composition of the solutions used.

There was no real difference in Ca contents of the cotyledons when H_2O and B (The Water treatments) were used. The average Ca contents for the two treatments changed from 2.9 mg at Stage 1 to 2.0 mg at Stage 4. Hence, on the average only about 31 percent of the Ca present in the cotyledons at Stage 1 was translocated by the fourth sampling period. These results indicate that Ca was not readily removed or translocated from the cotyledons and agrees with findings reported earlier.

When Hoagland treatments were used, the amounts of Ca in the cotyledons increased and then decreased. But the amounts found at the last stage of sampling were higher than what was found at Stage 1. There were no real differences between Hoagland-B and Hoagland in terms of CaCO found. The average Ca contents were 3.3 mg at Stage 1 and 3.6 mg at Stage 4. CaCO averaged 4.6 mg at Stages 2 and 3. There was a highly significant treatment effect which was due almost entirely to a highly significant Hoag effect (Table 16).

The amounts of Ca in the roots were similar for treatments from different groups. CaRO in the Water treatments was low, changing from an average of 0.3 mg at Stage 1 to 1.0 mg at Stage 4. In Hoagland treatments, CaRO averaged 1.0 mg and 8.2 mg at Stages 1 and 4, respectively. The analysis of varience in Table 16 shows that there was a highly significant treatment effect which was due almost entirely to the significant Hoag effect.

The amounts of Ca in the shoots increased with stage for all treatments but the rates and magnitudes of these changes differed. There was only a minimal increase in CaSH due to the Water treatments and the change was nearly identical for both H_2O and B. CaSH averaged 0.2 mg at Stage 1 and increased to 0.8 mg at Stage 4. The amounts of CaSH due to the Hoagland treatments were larger than that presented above and the rates of change were different for the two treatments. There was only 0.3 mg of CaSH at Stage 1 when Hoagland-B was used. However, because of rapid increases in CaSH which occurred between Stages 2 and 4, there was 27.0 mg by the fourth time of sampling. This was the maximum amount of Ca found in the shoots. When Complete Hoagland was used, there were 1.4 mg and 20.8 mg of CaSH at Stages 1 and 4, respectively. The rate of change in CaSH due to Hoagland increased until Stage 3 when it abruptly ceased increasing. Interpretations of these results are done later.

Variations in Ca concentration (expressed as percent of dry weights) in each plant portion as influenced by the different nutrient solutions are shown in Figure 20. The graphs show that there were striking differences in the Ca concentration in the plant parts studied. In general, however, there were similarities in percent Ca in plant parts due to treatments of similar composition. On this basis, there were two groups of treatments: Water treatments, where no Ca or other nutrients were supplied; and Hoagland treatments, where Ca and other essential nutrients were supplied. There were slight differences among treatments within each group.

The concentrations of Ca in the cotyledons due to Water treatments increased with stage. When only H_2O was used, CaCO was 0.4 percent at Stage 1; and increased to 0.6 percent by Stage 4. There was a 50 percent increase in Ca concentration by the fourth time of sampling. When B alone was used, CaCO changed from 0.3 percent at Stage 1 to 0.9 percent at Stage 4. This amounts to a 200 percent increase in Ca concentration due to the B treatment.

There was no difference between the Water treatments in Ca concentrations in the roots and shoots. In both plant portions and for both treatments, Ca concentrations were 0.1 percent at all stages of sampling.

There was a lot of variability in Ca concentrations in the different plant portions due to the Hoagland treatments. In general, there was an increase in the Ca concentration with stage in each plant part studied. There were slight differences in the trends due to each treatment.

When the Hoagland-B treatment was used, there were sharp increases in Ca concentrations of the cotyledons and shoots and a moderate increase in the roots. Calcium concentrations in the various plant portions were in the order cotyledons > shoots > roots. Examining each part individually, there were 0.3 percent and 1.4 percent Ca in the cotyledons at Stages 1 and 4, respectively, a net increase of 367 percent. In the shoots, Ca concentrations increased from 0.1 percent at Stage 1 to 1.0 percent at Stage 4. There was no change in percent CaSH due to Hoagland-B after Stage 3. Calcium concentration in the roots due to Hoagland-B increased from 0.2 percent at Stage 1 to 0.4 percent at Stage 4. It was unchanged between Stages 1 and 2 and again between Stages 3 and 4, hence the entire 100 percent increase occurred between Stages 2 and 3.

Calcium concentrations increased in all plant portions due to Complete Hoagland Solution. The maximum concentrations of 1.1 percent and 1.3 percent in the shoots and cotyledons, respectively, were attained at Stage 3 after which percent Ca declined. In the roots, a maximum concentration of 0.4 percent was attained at Stage 2 and maintained throughout the sampling period. Calcium concentrations of 0.2 percent and 0.3 percent were found in the roots and in shoots and cotyledons, respectively at Stage 1. Hence, between Stages 1 and 4, the increases in calcium concentrations were 100 percent in the roots; 250 percent in the shoots; and 175 percent in the cotyledons. These do not reflect the peak concentrations in the shoots and cotyledons solely for uniformity and consistency in reporting the results from this as well as other sections.

Magnesium Table A-12 in the Appendix presents the average Magnesium content found in the seedlings (TMg), roots (MgRO), shoots (MgSH), and in the cotyledons (MgCO) at each time of sampling as influenced by the different nutrient solutions. The values are in mg and have been presented graphically in Figure 21. Data for individual replications are presented in Table B-2 in the Appendix. Variations in the average magnesium concentrations (given as percent of dry weights) for each plant part are shown in Figure 22. Table B-1 in the Appendix presents the data on Mg concentrations for individual replications. The analyses of variance for the variables TMg, MgRO, MgSH, and MgCO are summarized in Table 17.

The graphs in Figure 21 show that the total amounts of magnesium in the seedlings varied widely among treatment groups but were similar for treatments with the same group. The groups were Water treatments and Hoagland treatments. Total magnesium due to Water treatments averaged about 4 mg at all stages of sampling for both treatments. There was no difference in TMg either with stage or due to the treatments. When Hoagland treatments were used, there was a significant increase in TMg with stage. The average TMg changed from 4 mg at Stage 1 to 18 mg at Stage 4, an increase of 350 percent. There was no difference between treatments in terms of the rates and amounts of TMg in the seedlings.

The analysis of variance for the variable TMg shows that treatment effect was highly significant (0.01 level); Hoag and B effects were significant at the 0.01 and 0.05 levels, respectively, but their interaction was nonsignificant (Table 17).

The amounts of Mg in various plant parts varied with different treatments but trends were similar within treatment groups. Magnesium content decreased with stage in the cotyledons and increased in the roots and shoots. There was no difference in the amount of Mg found in the cotyledons treated with different nutrient solutions or in the rates of decline of MgCO as influenced by the treatments. MgCO averaged approximately 2.98 mg at Stage 1 for all treatments. By Stage 4, there was approximately 1.75 mg which was approximately 59 percent of the amount present at Stage 1. This means only about 41 percent of the Mg content present at Stage 1 was translocated or removed from the cotyledons by

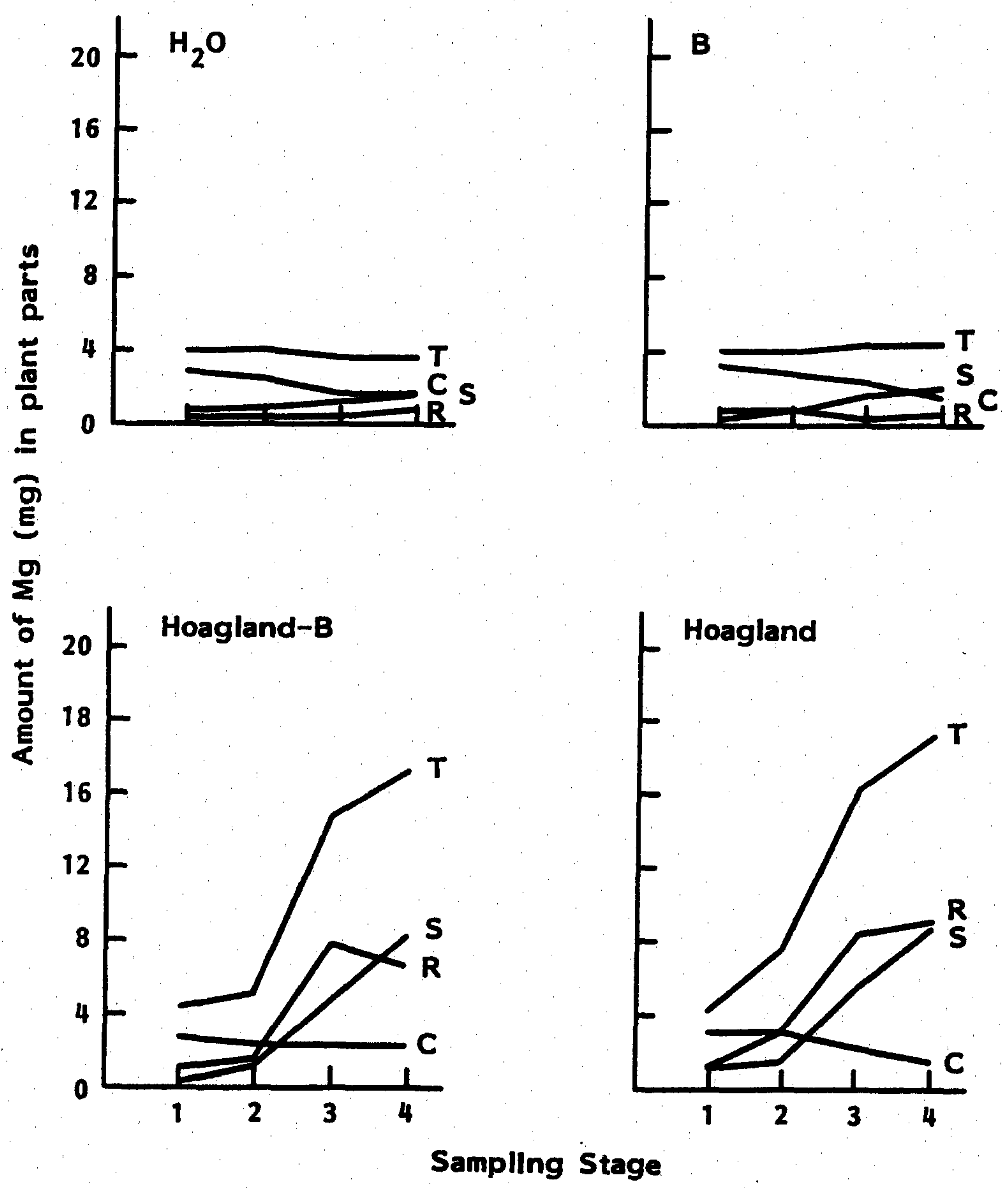

Figure 21. Variations in Mg content of whole plants (T), roots (R), shoots (S), and cotyledons (C) of soybean seedlings treated with different nutrient solutions

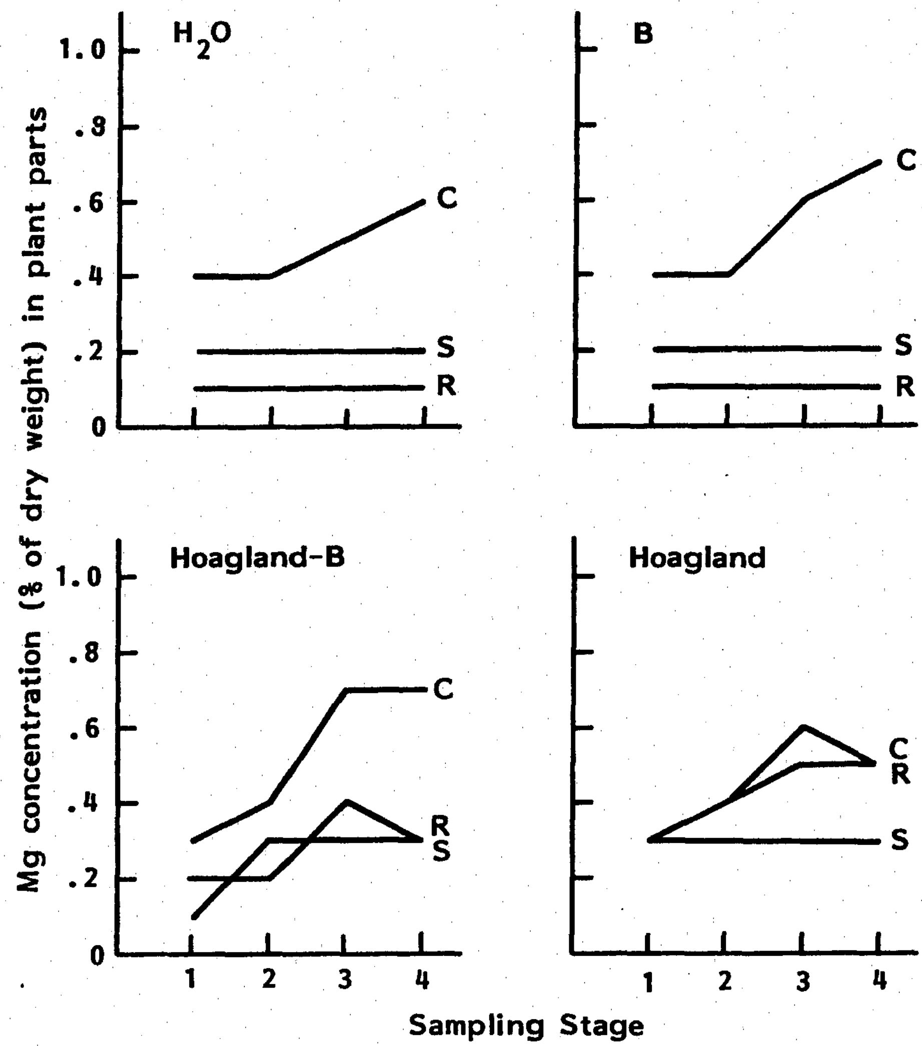

Figure 22. Variations in Mg concentration of roots (R), shoots (S), and cotyledons (C) of soybean seedlings treated with different nutrient solutions

Table 17. Analyses of variance of MgRO, MgSH, MgCO, and TMg -- B-Hoagland Experiment I

Source	DF	MS	F value	P>F
		MgRO		
Total	47	11.45		
Rep	2	1.10	1.73	ns
Stage	3	43.38	28.47	0.0001**
Trt	3	77.98	51.18	0.0001**
B	(1)	3.33	2.18	ns
Hoag	(1)	227.49	149.31	0.0001**
B x Hoag	(1)	3.11	2.04	ns
Trt x Stage	9	14.01	9.20	0.0001**
Error	30	1.53		
		MgSH		
Total	47	7.99		
Rep	2	1.49	1.32	ns
Stage	3	51.72	45.97	0.0001**
Trt	3	31.64	28.12	0.0001**
B	(1)	1.64	1.46	ns
Hoag	(1)	92.90	82.56	0.0001**
B x Hoag	(1)	0.38	0.34	ns
Trt x Hoag	9	9.86	8.76	0.0001**
Error	30	1.13		
		MgCO		
Total	47	0.53		
Rep	2	4.06	32.48	0.0001**
Stage	3	3.70	29.64	0.0001**
Trt	3	0.24	1.95	ns
B	(1)	0.13	1.07	ns
Hoag	(1)	0.37	2.96	0.0958†
B x Hoag	(1)	0.23	1.81	ns
Trt x Stage	9	0.15	1.23	ns
Error	30	0.12		

Table 17. (Continued)

Source	DF	MS	F value	P>F
		TMg		
Total	47	32.78		
Rep	2	7.23	3.61	.0394*
Stage	3	136.19	67.96	.0001**
Trt	3	219.07	109.32	.0001**
B	(1)	12.04	6.01	.0203*
Hoag	(1)	641.54	320.14	.0001**
B x Hoag	(1)	3.63	1.81	ns
Trt x Stage	9	44.47	22.19	.0001**
Error	30	2.00		

Stage 4. Table 17 shows that treatment effect on MgCO was nonsignificant in spite of the weakly (0.10 level) significant Hoag effect.

The amount of magnesium in the roots increased with stage due to each treatment. There were significantly larger amounts and increases due to Hoagland treatments as compared to Water treatments. There was no difference in MgRO obtained with the Water treatments. It averaged 0.4 mg at Stage 1 and 0.7 mg at Stage 4, an increase of 75 percent. On the average, only 17 percent of TMg due to Water treatments was found in the roots. The amounts of MgRO due to Hoagland treatments were different for each treatment. When Hoagland-B was used, MgRO changed from 1.0 mg at Stage 1 to a maximum of 8.0 mg at Stage 3 and then dropped to 6.8 mg at Stage 4. There was a 580 percent increase in MgRO between Stages 1 and 4 due to Hoagland-B. MgRO due to Complete Hoagland consistently increased with stage. It varied from 1.1 mg at Stage 1 to 9.2 mg at Stage 4 which was a 736 percent increase. A reduction in the rate of increase in MgRO occurred at Stage 3 but it was not as severe as that reported with Hoagland-B. The relative amounts of TMg found in the roots at Stage 4 were 39 percent and 48 percent, respectively, for Hoagland-B and Complete Hoagland treatments which were more than twice the proportion due to the Water treatments. Table 17 shows that the Hoag effect was highly significant as was Trt effect.

Magnesium contents of the shoots increased with stage for all treatments, the amounts were similar within treatment groups and widely different between groups. MgSH averaged 0.6 mg at Stage 1 and 1.7 mg at Stage 4 when Water treatments were used. There was no difference between H_2O and

B treatments. The amount of MgSH increased significantly when Hoagland treatments were used. There was an unusually low value obtained for Hoagland-B at Stage 1. This was identical to that found with Ca. With that exception, there was no difference in the amount of MgSH due to the Hoagland treatments. It averaged 0.7 mg and 8.5 mg at Stages 1 and 4, respectively. These were approximately 17 percent and 47 percent, respectively, of TMg obtained at those stages. By comparison, the proportions of TMg due to Water treatments averaged 11 percent and 18 percent, respectively, at Stages 1 and 4. The overall analysis of variance shows that Trt effect was highly significant due to the highly significant Hoag effect.

The variations in Mg concentrations (expressed as percent of dry weights) in plant parts are shown in Figure22. The trends were almost identical for the Water treatments but quite different for the Hoagland treatments. Magnesium concentration in the cotyledons increased with stage for all treatments. It fluctuated in the roots and shoots for the Hoagland treatments; and was constant for the Water treatments.

When H_2O was used, Mg concentration in the cotyledon changed from 0.4 percent at Stage 1 to 0.6 percent at Stage 4, all of the changes occurred after Stage 2. There was a similar but more rapid increase in percent Mg when B was used. MgCO increased from 0.4 percent (Stages 1 and 2) to 0.7 percent (Stage 4). There were no changes in percent MgRO and MgSH when H_2O and B were used. MgRO averaged 0.1 percent and MgSH averaged 0.2 percent at all stages of sampling for both B and H_2O treatments.

The variations in magnesium concentrations of the various plant parts due to Hoagland-B were the most dispersed of the treatments used. In the cotyledons, Mg concentration varied from 0.3 percent to 0.7 percent at Stages 1 and 4. In the roots, it varied from 0.2 percent at Stage 1 to a peak of 0.4 percent at Stage 3 then dropped to 0.3 percent at Stage 4. Magnesium concentration in the shoot increased from a minimum of 0.1 percent at Stage 1 to 0.3 percent at Stage 2 after which it remained constant. When Complete Hoagland was used, Mg concentrations increased in the cotyledons and roots but were unchanged in the shoots. The highest concentrations were found in the cotyledon where it changed from 0.3 percent at Stage 1 to 0.6 percent at Stage 3 and 0.5 percent at Stage 4. MgRO was 0.3 percent at Stage 1 and 0.5 percent at Stages 3 and 4. It averaged 0.3 percent in the shoots at all stages.

<u>Manganese</u> Data on manganese contents and concentrations found in plants treated with different nutrient solutions are presented in this section. The average Mn contents (in μg) found in the whole seedlings (TMn), in the roots (MnRO), shoots (MnSH), and in the cotyledons (MnCO) as influenced by different nutrient solutions are presented in Table A-13 in the Appendix; and also in the graphs in Figure 23. The experimental data showing Mn contents in the various plant parts for individual replications are presented in Table B-2 of the Appendix. The variations in Mn concentrations (expressed as μg/g of dry weight) in the various plant portions studied are shown in Figure 24. Data on Mn concentrations for individual replications are given in Table B-1 in the Appendix. The

analysis of variance for the Mn content variables are summarized in Table 18.

The total amounts of Mn in the seedlings differed for the different treatments. It averaged 39 μg when H_2O was used and was practically unchanged from one stage to the next. There was a slight increase in TMn with the B treatment. It changed from 40 to 53 μg at Stages 1 and 4, respectively. That was a 33 percent increase over the amount at Stage 1. Hence, taking Water treatments as a group we found a case in which TMn was essentially unchanged and another in which it increased by about 33 percent.

The total amounts of manganese in the seedlings increased substantially when Hoagland treatments were used. The largest increase was found in the plants treated with Complete Hoagland Solution. There were 41 and 83 μg of TMn at Stages 1 and 4, respectively, when Hoagland-B was used. This was a 102 percent increase in TMn from Stage 1 to 4. The amount of TMn due to Hoagland was significantly larger than that due to each of the other treatments even at Stage 1. It averaged 51 μg at Stage 1 and increased to 129 μg at Stage 4 which was a 158 percent increase. On a comparative basis, the TMn content found at Stage 4 for B, Hoagland-B and Hoagland were, respectively, 29 percent, 102 percent, and 215 percent more than the 41 μg for H_2O at the same stage. At Stage 1, the comparisons were as follows: 39 μg for H_2O; and increases in TMn of 3 percent, 5 percent, and 28 percent, respectively, for B, Hoagland-B, and Hoagland more than the 39 μg found when H_2O was used.

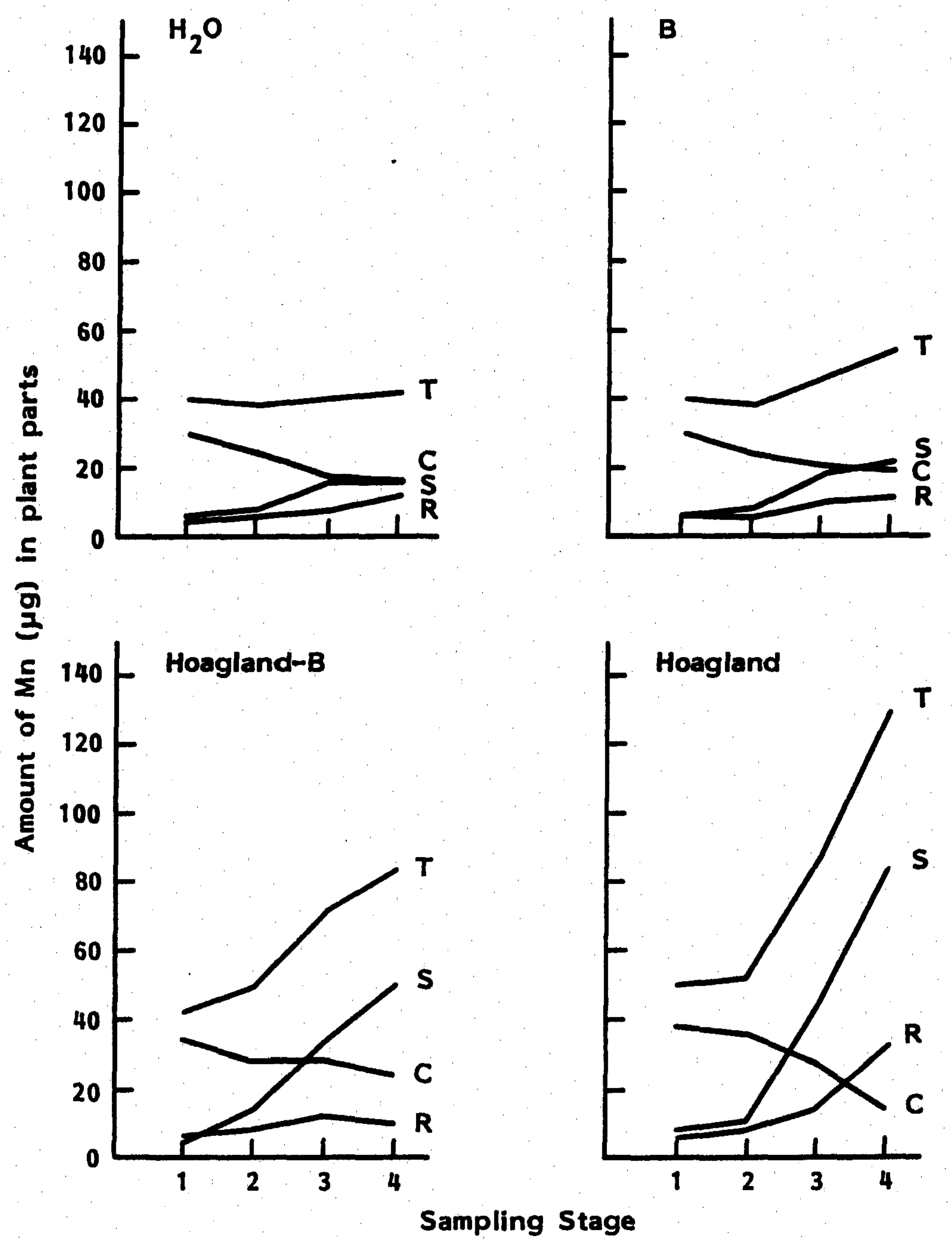

Figure 23. Variations in Mn content of whole plants (T), roots (R), shoots (S), and cotyledons (C) of soybean seedlings treated with different nutrient solutions

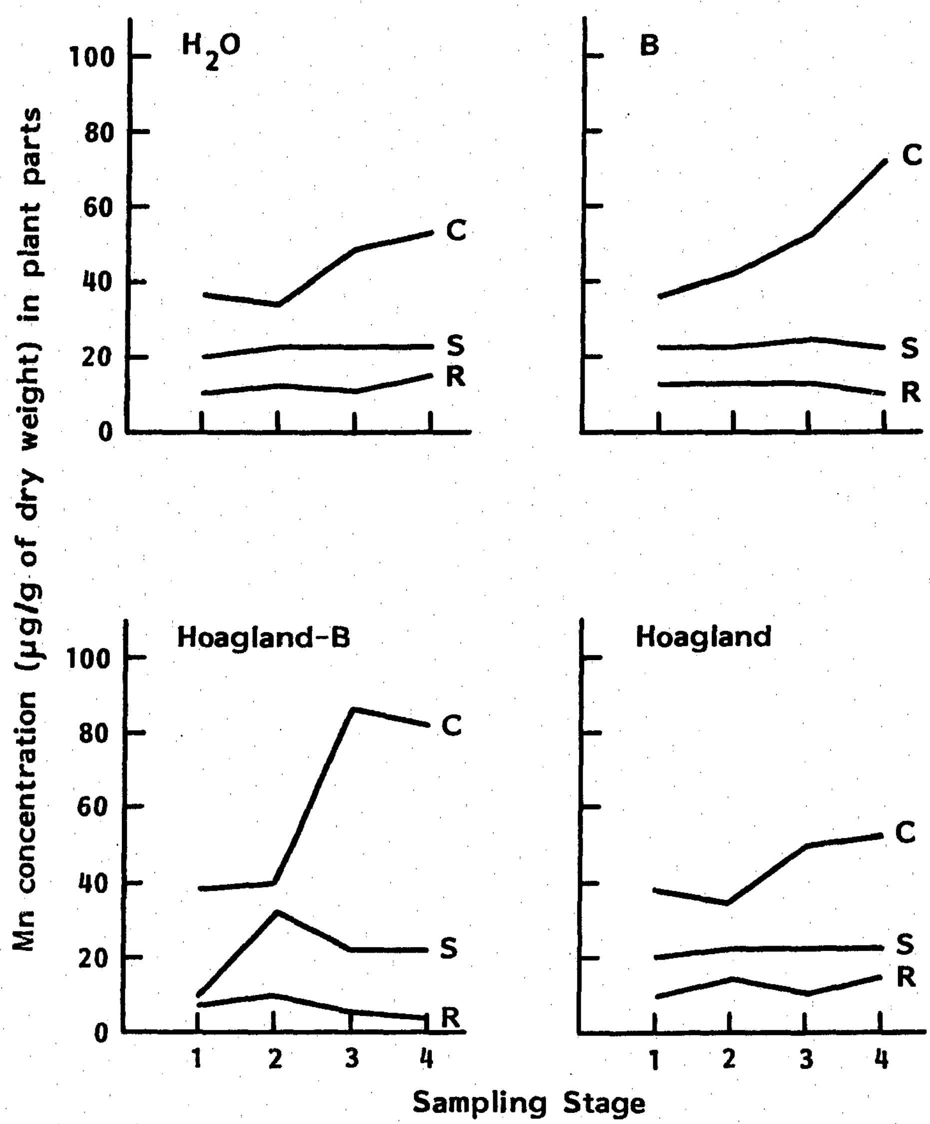

Figure 24. Variations in Mn concentration of roots (R), shoots (S), and cotyledons (C) of soybean seedlings treated with different nutrient solutions

Table 18. Analyses of variance of MnRO, MnSH, MnCO, and TMn -- B-Hoagland Experiment I

Source	DF	MS	F value	P>F
		MnRO		
Total	47	47.86		
Rep	2	23.01	1.86	ns
Stage	3	280.52	22.74	0.0001**
Trt	3	133.93	10.86	0.0001**
B	(1)	149.71	12.14	0.0015**
Hoag	(1)	173.17	14.04	0.0008**
B x Hoag	(1)	78.93	6.40	0.0169*
Trt x Stage	9	65.57	5.32	0.0002**
Error	30	12.34		
		MnSH		
Total	47	530.96		
Rep	2	93.82	0.65	ns
Stage	3	3418.15	23.83	0.0001**
Trt	3	1575.56	10.98	0.0001**
B	(1)	495.18	3.45	0.0730†
Hoag	(1)	4006.81	27.93	0.0001**
B x Hoag	(1)	224.69	1.57	ns
Trt x Stage	9	609.18	4.25	0.0013**
Error	30	143.46		
		MnCO		
Total	47	74.33		
Rep	2	465.48	30.57	0.0001**
Stage	3	399.06	26.21	0.0001**
Trt	3	214.09	14.06	0.0001**
B	(1)	15.96	1.05	ns
Hoag	(1)	621.79	40.84	0.0001**
B x Hoag	(1)	4.50	0.30	ns
Trt x Stage	9	29.60	1.94	0.0833†
Error	30	15.22		

Table 18. (Continued)

Source	DF	MS	F value	P>F
		<u>TMn</u>		
Total	47	792.43		
Rep	2	1097.27	5.32	.0105*
Stage	3	3092.88	15.00	.0001**
Trt	3	4078.31	19.78	.0001**
B	(1)	1480.97	7.18	.0118*
Hoag	(1)	10280.92	49.85	.0001**
B x Hoag	(1)	473.14	2.29	ns
Trt x Stage	9	816.60	3.96	.0021**
Error	30	206.23		

The proportion of TMn found in the various plant portions varied with the treatments used. The amounts of Mn decreased in the cotyledons and increased in the roots and shoots. MnCO averaged 29, 29, 33, and 37 μg, respectively, for H_2O, B, Hoagland-B, and Hoagland at Stage 1. By Stage 4, there were 15, 19, 23, and 15 μg for the treatments, respectively. These were approximately 52, 66, 70, and 41 percent of the initial amounts of Mn found for the four treatments, again in the order mentioned. Hence, between 30 and 59 percent of the MnCO at Stage 1 was translocated by Stage 4. The maximum and minimum amounts of Mn removed occurred with Complete Hoagland and Hoagland-B, respectively.

The amount of Mn in the roots increased with stage for all treatments. Except when Hoagland was used, there was no difference among treatments. MnRO averaged 5 μg at Stage 1 for all treatments, including Hoagland. It increased to an average of 11 μg for H_2O, B, and Hoagland-B and to 31 μg when Hoagland was used. These were a twofold increase for each of the three treatments and a sixfold increase for the Complete Hoagland treatment. On a comparative basis, there was nearly three times as much Mn in the roots of plants treated with Hoagland as was in plants which received each of the other treatments for sampling at Stage 4. The analyses of variance in Table 18 shows that treatment effect on MnRO was highly significant (0.01 level). The main effects of B and Hoag were also highly significant with their interaction significant at the 0.05 level. The Trt x Stage interaction was highly significant, as was the Stage effect.

Manganese content of the shoots increased with stage for all treatments but was different only with the Hoagland treatments. The amounts of MnSH found in plants treated with Hoagland-B and Hoagland were different from those for Water treatments and from one another. MnSH averaged 6 μg and 19 μg with the Water treatments; 3 μg and 50 μg with Hoagland-B; and 8 μg and 83 μg with Hoagland at Stages 1 and 4, respectively. Again, there was an unusually low value (3 μg) at Stage 1 for the Hoagland-B treatment. At Stage 4, there was a 1:3:4 ratio of MnSH due to the Water treatments, Hoagland-B, and Hoagland, respectively. The analysis of variance in Table 18 shows that there was a highly significant treatment effect due largely to a highly significant Hoag main effect. The main effect of B was significant only at the 0.10 level.

The variations in Mn concentrations (expressed as μg/g) in different plant portions as influenced by the nutrient solutions used are shown in Figure 24. In general, Mn concentration increased in the cotyledons and was essentially unchanged in the roots and shoots, except when Hoagland-B was used where it declined with successive times of sampling. Variations in Mn concentration in the cotyledons were identical for the H_2O and Complete Hoagland treatments and different when B and Hoagland-B were used. The minimum variations in Mn concentration occurred with the H_2O and Hoagland treatments where manganese concentration in the cotyledons averaged 37 μg/g at Stage 1 and increased to 51 μg/g at Stage 4. There was a steady increase in Mn concentration in the cotyledons due to B throughout the sampling period. It changed from 35 μg/g at Stage 1 to 41, 52, and 72 μg/g at Stages 2, 3, and 4, respectively; and was intermediate relative to the other treatments. Manganese concentration in the cotyledons varied most when Hoagland-B was used. It was 37 μg/g at Stage 1, increased to a maximum concentration of 86 μg/g at Stage 3 and then declined to 81 μg/g at Stage 4.

Except when Hoagland-B was used, there was little change in Mn concentration in the roots with treatment and with times of sampling. It averaged 11 μg/g with B and was 12 μg/g with H_2O and Complete Hoagland Solution. When Hoagland-B was used, Mn concentration in the cotyledons first increased and then decreased. It averaged 8 μg/g at Stage 1; increased to 10 μg/g at Stage 2; then steadily decreased to 6 and 4 μg/g at Stages 3 and 4, respectively.

The variations in Mn concentrations in the shoots were similar to those in the roots but were slightly higher. There was essentially no change due to B, H_2O and Hoagland. The concentration of Mn in the shoots averaged 22 μg/g when B was used and 21 μg/g with H_2O and Hoagland over all stages of sampling. When Hoagland-B was used Mn concentration changed from 9 μg/g at Stage 1 to a maximum of 31 μg/g at Stage 2 and decreased thereafter. At Stage 4, there was a manganese concentration of 21 μg/g due to Hoagland-B.

<u>Boron</u> The amounts and concentrations of B in soybean seedlings and various portions thereof as influenced by different nutrient solutions at each stage of sampling are reported in this section. Boron content data are in μg while concentrations are given in μg/g of plant dry

matter. The average B contents of the seedlings (TB), and of the roots (BRO), shoots (BSH), and of the cotyledons (BCO) are presented in Table A-14 in the Appendix. Figures 25 and 26 show variations in the average B contents and concentrations, repectively, with stage as influenced by the different nutrient solutions used. Data on B concentrations and B contents for individual replications are presented, respectively, in Tables B-1 and B-2 in the Appendix. The analysis of variance for the B content variables (TB, BRO, BSH, and BCO) are summarized in Table 19.

The total amount of B in the seedlings was influenced by the nutrient solutions. It was essentially unchanged when only H_2O was used but increased due to all other treatments. TB varied from 43 to 46 μg and averaged 45 μg when H_2O was used. Statistically, there was no difference in TB due to the various treatments for sampling of Stage 1. However, for samples taken at later stages, especially at Stages 3 and 4, there were significant differences in TB among treatments. When only B was used, TB averaged 42 μg at Stages 1 and 2, increased to 47 μg at Stage 3 and to 55 μg by Stage 4. This was a net increase of 13 μg or about 31 percent over the amount of Stage 1. There was a larger increase in TB due to Hoagland-B even though the treatment did not contain boron. TB increased from 41 μg at Stage 1 to 65 μg at Stage 4; an increase of 24 μg which was about 59 percent of the initial amount. The largest increase in TB occurred when Complete Hoagland Solution was used. TB increased from 50 μg to 118 μg at Stages 1 and 4, respectively. That was a net increase of 68 μg or about 136 percent more than the amount found at Stage 1.

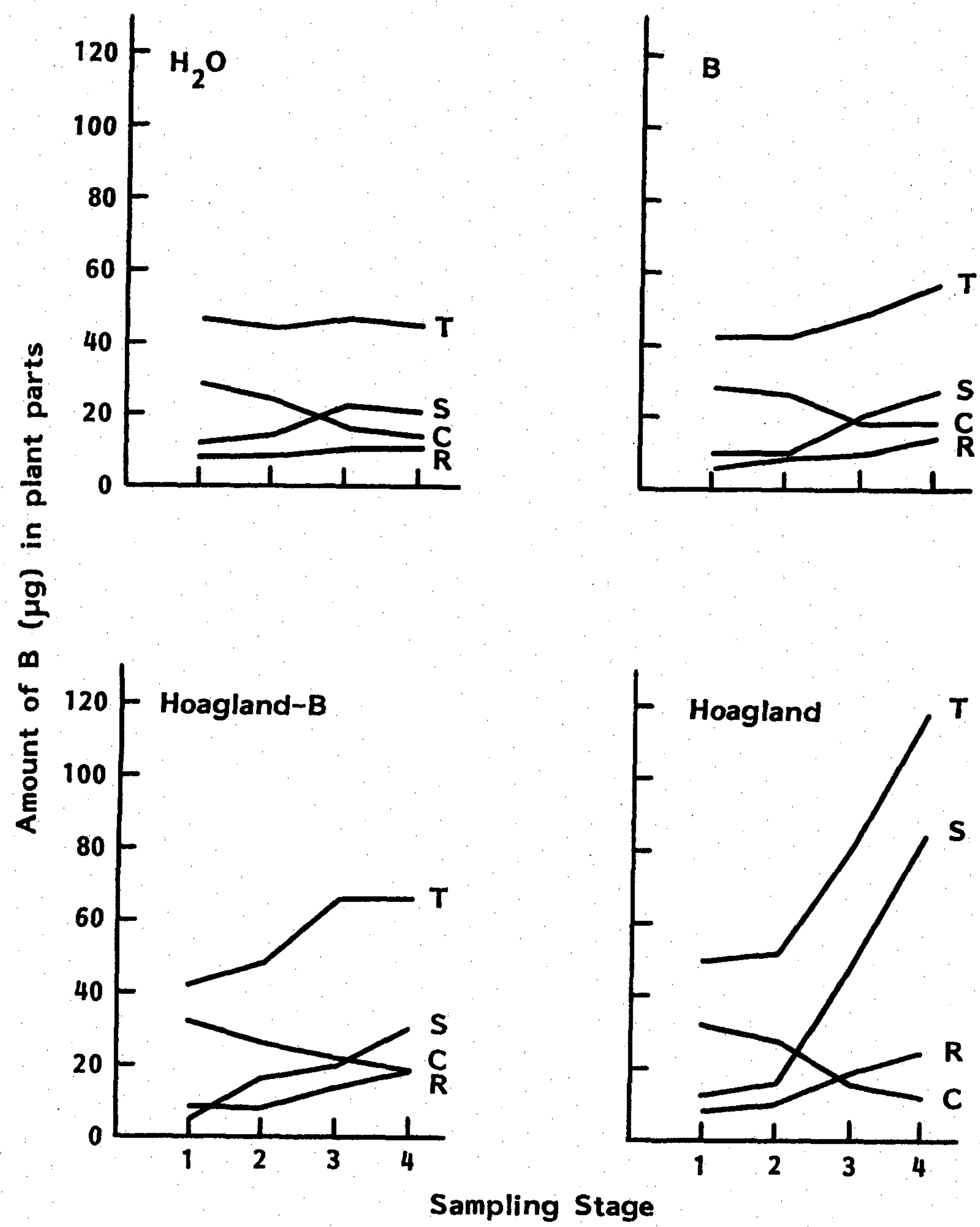

Figure 25. Variations in B content of whole plants (T), roots (R), shoots (S), and cotyledons (C) of soybean seedlings treated with different nutrient solutions

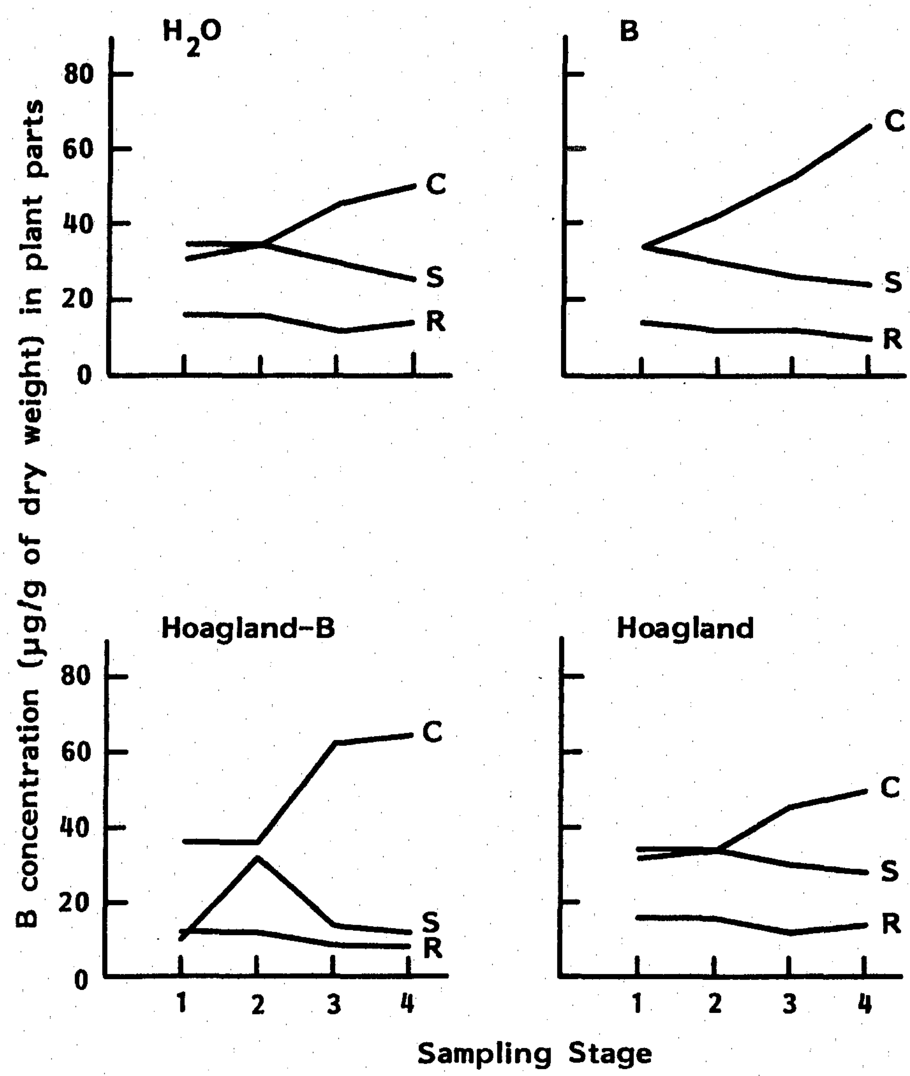

Figure 26. Variations in B concentration of roots (R), shoots (S), and cotyledons (C) of soybean seedlings treated with different nutrient solutions

Table 19. Analyses of variance of BRO, BSH, BCO, and TB -- B-Hoagland Experiment I

Source	DF	MS	F value	P>F
		BRO		
Total	47	37.46		
Rep	2	69.79	5.10	0.0124*
Stage	3	220.58	16.11	0.0001**
Trt	3	105.83	7.73	0.0006**
B	(1)	31.15	2.27	ns
Hoag	(1)	273.85	20.00	0.0001**
B x Hoag	(1)	12.50	0.91	ns
Trt x Stage	9	25.68	1.88	0.0951†
Error	30	13.69		
		BSH		
Total	47	434.98		
Rep	2	306.72	2.64	0.0881†
Stage	3	2270.40	19.52	0.0001**
Trt	3	1578.64	13.57	0.0001**
B	(1)	1545.10	13.28	0.0010**
Hoag	(1)	1655.01	14.23	0.0007**
B x Hoag	(1)	1535.81	13.20	0.0010**
Trt x Stage	9	532.62	4.58	0.0007**
Error	30	116.33		
		BCO		
Total	47	59.05		
Rep	2	399.31	45.44	0.0001**
Stage	3	498.62	56.75	0.0001**
Trt	3	30.56	3.48	0.0280*
B	(1)	0.23	0.03	ns
Hoag	(1)	35.83	4.08	0.0525†
B x Hoag	(1)	56.62	6.33	0.0175*
Trt x Stage	9	13.94	1.59	ns
Error	30	8.79		

Table 19. (Continued)

Source	DF	MS	F value	P>F
		TB		
Total	47	563.13		
Rep	2	2036.89	12.65	.0001**
Stage	3	1680.29	10.44	.0001**
Trt	3	2404.11	14.94	.0001**
B	(1)	1972.38	12.26	.0015**
Hoag	(1)	3996.24	24.83	.0001**
B x Hoag	(1)	1243.71	7.73	.0093**
Trt x Stage	9	590.52	3.67	.0034**
Error	30	160.92		

The analysis of variance for the variable TB presented in Table 19 shows that there was a highly significant effect of treatment. The main effects of B and Hoag along with their interaction were also highly significant. The model used had an R^2 of 0.82 which indicates that it was quite satisfactory for explaining the variabilities in the total amounts of B in the seedlings.

Although B content decreased in the cotyledons and increased in the roots and shoots with advancing stage of sampling for all treatments in the study, the relative amounts of B found in various portions of the seedlings varied with each treatment. The variations in the amounts of B found in the plant portions due to each treatment was of greater interest to us than the proportions in those portions. These results are presented in the following section.

There were 27 μg and 14 μg of B in the cotyledons at Stages 1 and 4, respectively, when only H_2O was used. This means that 13 μg or approximately 48 percent of the initial amount of B in the cotyledons at Stage 1 was translocated or removed by Stage 4. When B alone was in solution, nearly 39 percent of the initial amount of B in the cotyledon was removed by Stage 4. Boron content averaged 28 μg at Stage 1 and 17 μg at Stage 4 -- a loss of 11 μg. The amount of B in the cotyledons at Stage 1 due to the Hoagland-B treatment averaged 31 μg which was slightly more than that due to H_2O or B alone. This was unusual. By Stage 4, the amount had declined to 18 μg which was 58 percent of the initial amount. Hence, nearly 42 percent had been removed between Stages 1 and 4. The maximum loss in BCO occurred when Hoagland was used. Nearly 20 μg or about 65 percent of the initial amount of B in the cotyledons (31 μg) was removed by Stage 4. The treatments ranked as follows based on the percentage of B removed from the cotyledons: Hoagland > H_2O > Hoagland-B > B. Compared to other nutrients, B was moderately removable from the cotyledons.

The amount of B in the roots was very strongly affected by treatments. When only H_2O was used, BRO changed from 7 μg at Stage 1 to 9 μg at Stage 4, an increase of 29 percent. BRO averaged 5 μg and 13 μg at Stages 1 and 4, respectively, when B alone was used which was a 160 percent increase. When Hoagland-B was used, BRO changed from 7 μg at Stage 1 to 18 μg at Stage 4. That was a 157 percent increase in B content. The increase in B content due to Hoagland was 243 percent as BRO changed from 7 μg to 24 μg at Stages 1 and 4, respectively. Table 19 shows that treatment effect, which was due solely to the significant (0.01 level) Hoag main effect, was highly significant.

The amount of B in the shoots increased with stage and was enhanced by the different nutrients. The amounts due to H_2O was less than those due to B, Hoagland-B, and Hoagland, indicating that those treatments had a positive influence on the amount of B in the shoots. When only H_2O was used, BSH increased from 11 μg at Stage 1 to 20 μg at Stage 4, nearly a twofold increase. There was slightly less BSH at Stage 1 when B alone was used, nevertheless, the amount of BSH at Stage 4 was more than that obtained with H_2O. BSH changed from 9 μg to 25 μg at Stages 1 and 4, respectively, due to the B treatment. When Hoagland-B was used, there was a significantly lower B content in the shoots at Stage 1 relative to the other treatments, including H_2O. There were 3 µg and 29 µg of BSH at Stages 1 and 4, respectively, when Hoagland-B was used. The amount of BSH due to Hoagland averaged 12 µg at Stage 1 and 83 µg at Stage 4. To summarize these results, based on the amounts found at Stage 4, BSH averaged 20 µg with H_2O. The increases due to B, Hoagland-B, and Hoagland were, respectively, 5 µg (25 percent), 9 µg (45 percent), and 63 µg (315 percent). These increases in B content were significant.

The analyses of variance for the variable BSH show that treatment effect was highly significant and that B and Hoag main effects and their interaction were also highly significant. The implications of these findings will be dealt with in the Discussion section.

Figure 26 shows the variations in B concentrations in each plant portion as influenced by the various nutrient solutions. In general, B concentration (given in µg/g dry weight) increased in the cotyledons and decreased slightly in the roots and shoots.

Boron concentration in the cotyledons increased with stage. The trends due to H_2O and Hoagland were identical and were lower than those found with B and Hoagland-B. The concentration due to H_2O and Hoagland averaged 34 µg/g at Stage 1 and increased to 49 µg by Stage 4. When B alone was used, it was 33 µg/g at Stage 1 and increased to 66 µg/g at Stage 4 which was the maximum B concentration found in the cotyledon. Although the Hoagland-B treatment did not contain any boron, an increase in B concentration occurred when it was used. Boron concentration in cotyledons changed from 35 μg/g at Stage 1 to 63 μg/g at Stage 4. The interpretations of these fluctuations are in the Discussion section which follows later.

There was little variation in B concentrations of the roots as influenced by the various nutrient solutions. The concentrations were slightly higher for the H_2O and Hoagland treatments where it averaged 14 μg/g and ranged from 11 μg/g (Stage 3) to 16 μg/g at Stage 4. Boron concentrations in the roots due to B alone averaged 12 μg/g and varied from 13 μg/g at Stage 1 to 10 μg/g at Stage 4. When Hoagland-B was used the concentration of B in the roots was consistently lower than that reported for the other treatments. It averaged 9 μg/g and ranged from the minimum of 7 μg/g obtained at Stages 3 and 4 to 12 μg/g at Stage 1. In general, there was a decline in the concentration of B in the roots with successive stages of sampling. On a comparative basis, the treatments ranked as follows based on the concentration of B in the roots: H_2O = Hoagland > B > Hoagland-B.

Boron concentrations in the shoots were nearly twice as much as those in the roots; as in the roots, declined with advancing stages of sampling. The trends were again identical when Hoagland and H_2O were used where an average of 30 μg/g was found for all stages of sampling. Values for individual stages varied from 27 to 33 μg/g, the highest occurring at Stage 2. Boron concentration in the shoots due to the B treatment averaged 28 μg/g for all stages and varied from 24 to 34 μg/g. There was a progressive decline in B concentration with stage. When

Hoagland-B was used, an average B concentration of 16 μg/g was found in the roots for all stages. Except for the unusually low value at Stage 1, there was a decline in B concentration with advancing stage of sampling. This was as expected.

Other micronutrients The concentrations and amounts of several micronutrients (Al, Cu, Fe, Na, and Zn) in each portion of the plants due to different nutrient solutions are presented in Tables B-1 and B-2, respectively. Simple linear correlation analysis between the means of nutrient content variables for these nutrients and the ones already investigated (P, K, Ca, Mg, Mn, and B) were done. The simple correlation coefficients between means of nutrient content variables higher than $r > \pm 0.60$ for each plant portion are given in Table 20, thus showing those nutrients with a high degree of association between them in each portion of the plant.

The correlation analysis showed that K, Ca, Mg, Mn, and B were highly intercorrelated ($r = .69$ to $.98$) in the roots. Hence, among the nutrients already investigated, only P was not correlated ($r > \pm .60$) with any other nutrient; however, like the other nutrients it was highly correlated with at least one of the additional micronutrients (Na, Fe, Cu, Zn, and Al). P was highly correlated with Zn ($r = .84$) which was also highly correlated with Mn ($r = .72$) and with Cu ($r = .84$). Na was highly correlated with Mg ($r = .78$) with Ca ($r = .77$), and with Al ($r = .74$). A correlation coefficient of $r = .67$ between Ca and Al indicated a moderately high degree of correlation. B was highly correlated with each of the addi-

Table 20. Simple linear correlations between means of nutrient content variables for each plant portion -- B-Hoagland experiment

	P	K	Ca	Mg	Mn	B	Na	Fe	Cu	Zn	Al
					ROOT $r > 0.60$						
P	-	-	-	-	-	-	-	-	-	.84	-
K		-	.91	.94	.88	.95	-	-	.62	-	-
Ca			-	.98	.69	.90	.77	-	-	-	.67
Mg				-	.72	.90	.78	-	-	-	-
Mn					-	.89	-	-	.71	.72	-
B						-	.69	.64	.69	.62	.66
Na							-	-	-	-	.74
Fe								-	-	-	.88
Cu									-	.84	-
Zn										-	-
Al											-
					SHOOT $r > 0.60$						
P	-	.97	.88	.96	.99	.92	.71	.91	.97	.97	.95
K		-	.95	.98	.97	.89	.64	.85	.91	.92	.93
Ca			-	.97	.87	.71	.56	.82	.79	.85	.91
Mg				-	.96	.82	.66	.91	.91	.95	.96
Mn					-	.94	.69	.91	.97	.97	.94
B						-	.68	.78	.93	.87	.83
Na							-	.76	.74	.74	.75
Fe								-	.93	.95	.96
Cu									-	.97	.95
Zn										-	.96
Al											-
					COTYLEDON $r > 0.60$						
P	-	.82	-	.84	.61	.88	-	.92	.97	.98	-
K		-	-	.87	.86	.84	-	.78	.89	.85	-
Ca			-	-	.65	-	-	-	-	-	-
Mg				-	.89	.96	-	.85	.88	.86	-
Mn					-	.85	-	.67	.74	.70	-
B						-	-	.92	.92	.92	-
Na							-	-	-	-	-
Fe								-	.93	.92	-
Cu									-	.97	-
Zn										-	-
Al											-

tional micronutrients in the roots (r = .62 to .69). There were several cases of three-nutrient intercorrelations in the roots since two nutrients that were highly correlated were also correlated with a third nutrient. Most of these intercorrelations involved B which was highly correlated with all nutrients in the study except P. These correlations suggest that with a high degree of probability one would expect to find in the roots, at least, similarities in variations between the micronutrients and at least one of the nutrients already thoroughly investigated. Hence, further analysis of the data was not deemed expedient.

There were very high correlations between the various nutrients in the shoots. The nutrients already investigated (P, K, Ca, Mg, Mn, and B) were highly intercorrelated (r = .82 to .99). Following were some of the correlations between the micronutrients and these nutrients: A correlation coefficient of r = .71 was found for Na with P. Fe was highly correlated (r = .91) with P, Mg, and Mn. There were high correlation coefficients for Cu with P and Mn (r = .97); and for Zn with P and Mn (r = .97). Al was highly correlated with Mg (r = .96). Intercorrelations between micronutrients existed in the shoots but these were not of major interest to us.

In the cotyledons, all of the already investigated nutrients were highly intercorrelated (r = .61 to .96) except Ca which was only correlated with Mn (r = .65). Three of the additional micronutrients were highly correlated with at least one of the nutrients above. Fe was highly correlated with P and B (r = .92). There was a correlation coefficient of r = .97 for Cu with P. Zn was highly correlated with P (r = .98). Na and Al were not correlated (r > $\pm$ .60) with any of the nutrients in the study. However, since these nutrients (though present in large quantities) are not known to be essential for soybeans, we did not find it necessary to investigate them any futhre.

Ca-Mn-Hoagland Experiment II

Only dry weight data were collected in the remaining experiments of this study. Hence, the rest of the results section deals entirely with dry weights. All values are in mg/9 plants. Table A-15 in the Appendix summarizes average dry weights of the roots (ROWT), shoots (SHWT), cotyledons (COWT), and of the whole seedlings (TWT) at each stage of sampling for each treatment. Figure 27 is a graphic presentation of the data. The experimental results showing data for individual replications are presented in Table B-3 in the Appendix.

The graphs in Figure 27 could be grouped into three sets based upon the degree of variability in dry weight. Group I consists of H_2O; Group II consists of Mn, Hoagland-Ca, and Hoagland - (Ca + Mn); and Group III consists of Ca, Ca + Mn, Hoagland-Mn, and Complete Hoagland Solution. When only H_2O was used (Group I) there was a decline in TWT with time; ROWT and SHWT increased and then decreased, and COWT consistently declined with time. For treatments in Group II TWT increased due to increases in ROWT and SHWT, in spite of the decline in COWT. Overall, TWT, ROWT, and SHWT increased to about twofold their initial amounts by Stage 4; COWT

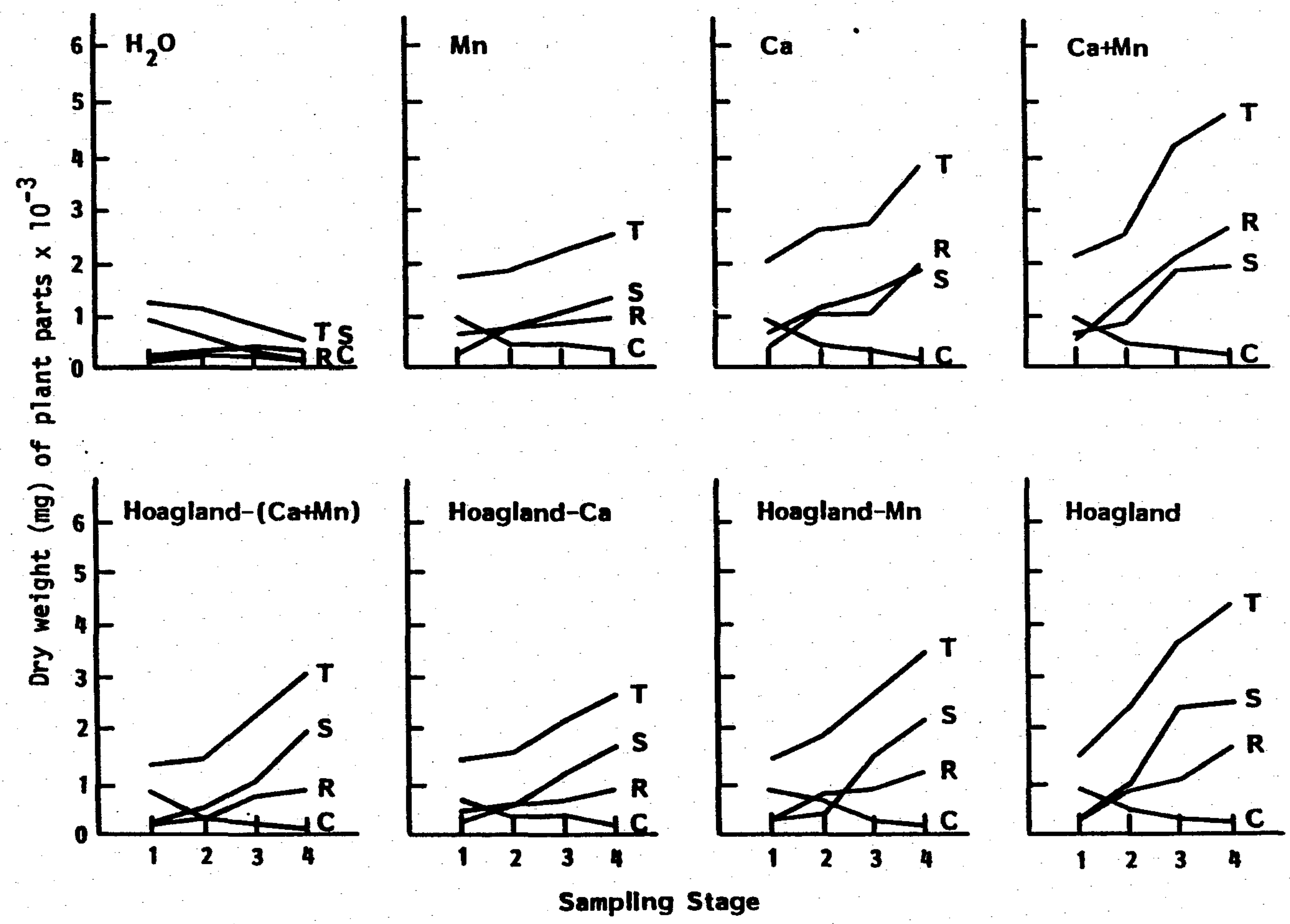

Figure 27. Variations in total dry weights (T), and dry weights of roots (R), shoots (S), and cotyledons (C) of soybean seedlings treated with different nutrient solutions

declined to about one-third the original amount. The treatments in Group II were all similar in one respect: they were lacking in Ca.

The maximum dry weights were obtained with treatments in the third group. Treatments in this category differed from those of the first and second groups because the former supplied Ca whereas the latter two did not. TWT changed from an average of 1,760 mg at Stage 1 to 4,130 mg at Stage 4, a 135 percent increase. While there was little difference in TWT among individual treatments, the proportions found in different plant parts differed. In general, supplying Ca and Mn in water appeared to be more favorable for root growth; when supplied in Hoagland Solution, they appeared to be more favorable for shoot growth. As with the previous groups, treatments did not appear to have any effect on cotyledon dry weight. The amount of decline in COWT was similar for all treatments. COWT averaged 880 mg for all treatments at Stage 1 and 170 mg at Stage 4, for an average loss of 80 percent of original COWT.

Ca-Mg-Hoagland Experiment II

Average dry weights of roots (ROWT), shoots (SHWT), cotyledons (COWT) and of the whole seedlings (TWT) are summarized in Table A-16 in the Appendix. Dry weights in each plant part for individual replications are presented in Table B-3, also in the Appendix.

Based upon the total dry weights obtained, there were three groups of treatments. The first group comprised the H_2O treatment. There was a decline in TWT following relatively steady growth during the first two stages. This decline was due to severe die-back of seedlings coupled with the normal decline in cotyledon dry weights. TWT averaged 1240 and 500 mg at Stages 1 and 4, respectively, a decline of 60 percent. The die-back of roots and shoots was expected as was found in other experiments, but the severity here was unexpected. We cannot fully explain this occurrence.

The second group of treatments consisted of Mg, Ca + Mg, Hoagland-Ca, Hoagland-Mg, and Hoagland - (Ca + Mg). Dry weights obtained with these treatments were larger than that for H_2O but were significantly less than those for the third group. The average TWT for Group II was 1400 mg at Stage 1 and 2260 mg at Stage 4. The relative amounts of TWT in roots and shoots varied only slightly. Root weights were slightly larger than shoot weights at Stage 1 while the opposite was true at Stage 4. This suggests that root growth preceded shoot growth; however, by the third and fourth times of sampling shoot growth exceeded root growth.

The maximum total dry weights were obtained with treatments in the third group. These treatments were Complete Hoagland Solution and Ca. TWT averaged 1720 mg at Stage 1 for both treatments and approximately 4120 mg at Stage 4. The relative amount of TWT found in the roots were 22 and 45 percent at Stages 1 and 4, respectively. That for the shoots was 52 percent at Stages 1 and 4.

There was a decline in COWT irrespective of treatment, meaning treatments did not affect or alter the loss of cotyledon weight. COWT averaged 820 mg and varied from 660 to 940 mg at Stage 1 for all treatments. It varied from 110 to 300 mg and averaged 180 mg at Stage 4 for an average total loss of 640 mg or about 78 percent. This was as expected and consistent with findings from other experiments already presented.

Ca-Mn-Hoagland Experiment III

Table A-17 in the Appendix summarizes the average dry weights of roots (ROWT), shoots (SHWT), cotyledons (COWT), and total plants (TWT) of soybean seedlings treated with different nutrient solutions. Figure 28 is a graphic presentation of these values. Experimental data showing dry weights for individual replications are presented in Table B-4 in the Appendix.

Based upon the amount of TWT obtained, the graphs in Figure 28 may be classified into three groups. Group I consists of H_2O only. TWT remained constant during the first three stages and then declined at Stage 4. This was due to declines in ROWT and SHWT after Stage 3 as a result of die-back of root and shoot tips. This die-back was due to the lack of nutrients in the cotyledons which by that time had lost over 80 percent of their original weights. The proportions of TWT found in roots and shoots for the H_2O treatments (Group I) varied with stage. ROWT was 33 and 58 percent of TWT at Stages 1 and 4, respectively; and SHWT averaged 17 and 33 percent at Stages 1 and 4, respectively.

The second group of treatments consisted of Ca, Mn, Ca + Mn, Hoagland-Ca, and Hoagland - (Ca + Mn). Dry weights obtained with these treatments were intermediate, relative to those for Groups I and III. TWT averaged 2020 mg and varied from 1840 to 2130 mg for the five treatments. By Stage 4, TWT averaged 3940 mg and varied from 3510 to 4270 mg. In general, TWT was almost evenly divided between roots and shoots.

The maximum dry weights were obtained with Group III which consisted of Hoagland-Mn and Complete Hoagland Solution. TWT averaged 2200 mg at Stage 1. By Stage 4, it had increased to 5530 mg, an increase of about 150 percent. Although TWT was essentially the same for both treatments, there were differences in the proportions found in the roots and shoots. When Hoagland-Mn was used the relative amounts of TWT in roots and shoots were equal, despite differences during earlier stages of sampling. By Stage 4, approximately 46 percent and 50 percent of TWT respectively were found in the roots and shoots. When Complete Hoagland Solution was used, significantly more shoots than roots were produced. At Stage 4, the proportion of TWT found in roots and shoots were 36 percent and 59 percent, respectively. Figure 28 shows that a substantial amount of this shoot weight accumulation occurred after Stage 3. Approximately 1600 mg or about one-half of the total SHWT was produced during this interval.

B-Hoagland Experiment III

There were four treatments in this experiment: H_2O, B, Hoagland-B, and Complete Hoagland Solution. The average dry weights are summarized in Table A-18 in the Appendix. The experimental data showing dry weights for individual replications are presented in Table B-4, also in the Appendix.

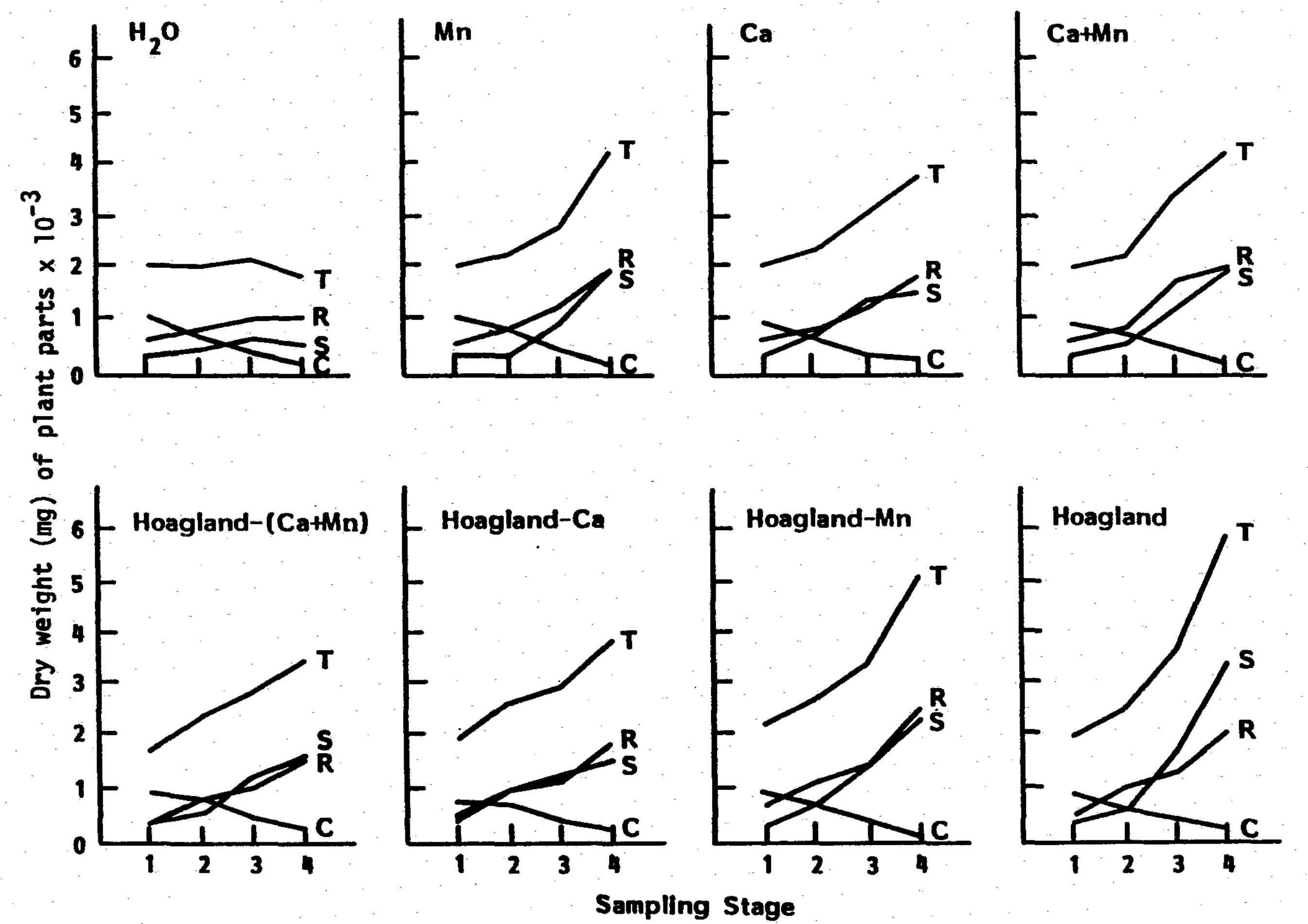

Figure 28. Variations in total dry weights (T), and dry weights of roots (R), shoots (S), and cotyledons (C) of soybean seedlings treated with different nutrient solutions

Total dry weights obtained were different for individual treatments, although there were some similarities for treatments of similar composition. Dry weights for Water Solution treatments were similar except at the final stage of sampling. TWT changed only slightly when only H_2O was used. It averaged 2130 mg at Stages 1 and 2; 2190 mg at Stage 3; and declined to 1860 mg at Stage 4. When B alone was used, it averaged 2130, 2220, 2620, and 3260 mg at Stages 1, 2, 3, and 4, respectively. Compared to the first treatment, there was about 43 percent increase in TWT. The increases in TWT were due mainly to increases in ROWT which occurred at Stages 3 and 4. Except for a sharp increase in SHWT which occurred at Stage 4, there was little difference between the two treatments with respect to SHWT obtained. This abrupt increase was unique and one we cannot explain.

Total dry weights of plants increased significantly when Hoagland Solution treatments were used. The Hoagland treatments used were Hoagland-B and Complete Hoagland Solution. Although TWT increased with successive stage of sampling, the largest increases occurred during the last two sampling periods. There was slightly more TWT when Complete Hoagland was used than was obtained with the Hoagland-B treatment. This is the opposite of what was found in an earlier experiment. There was no difference in TWT at Stages 1 and 2, but by Stage 4 the differences were highly significant. TWT averaged 2110 mg at Stage 1 and 2540 mg at Stage 2. At Stage 4 TWT averaged approximately 4720 mg (Hoagland-B) and 5920 mg (Complete Hoagland).

The relative amounts of TWT found in roots and shoots were essentially the same for both treatments. About 36 percent and 59 percent of TWT were found in roots and shoots, respectively when Complete Hoagland was used; compared to 35 percent and 61 percent, respectively, when Hoagland-B was used.

Cotyledon dry weights declined with stage and were not affected by treatment. COWT averaged 1080 mg at Stage 1 and about 240 mg at Stage 4 for all four treatments. Hence, for all treatments there was a loss of approximately 75 percent by the fourth time of sampling. These results were consistent with our findings in other experiments and with what was expected.

Ca-Mg-Hoagland Experiment III

Average dry weights of the whole plants (TWT), and of the roots (ROWT), shoots (SHWT), and cotyledons (COWT) of soybean seedlings treated with different nutrient solutions are summarized in Table A-19 in the Appendix. The experimental data showing results for individual replications are presented in Table B-4, also in the Appendix.

On the basis of total dry weights obtained, there were three groups of treatments. Group I consisted of the H_2O treatment alone; Group II consisted of the Ca, Mg, Hoagland - Ca, and Hoagland - (Ca + Mg) treatments; and Group III consisted of Ca + Mg, Hoagland-Mg, and Complete Hoagland Solution. The maximum TWT were obtained with treatments in Group III and the minimum was obtained with Group I. TWT values for treatments in Group II were intermediate relative to those for Groups I and III.

The total dry weight obtained for plants treated with H_2O only (Group I) remained essentially unchanged during the first three sampling stages but declined at the fourth time of sampling. TWT averaged 2130 mg at Stages 1 and 2, 2190 mg at Stage 3 and 1860 mg at Stage 4. The decline in TWT occurred as a result of die-back of roots and shoots coupled with continued decline in the cotyledon weights. Die-back of terminal, meristematic tissues are generally associated with severe calcium deficiency and have been discussed by a number of authors (Tisdale and Nelson, 1975; Bidwell, 1974; Epstein, 1972; etc.). In plants treated with H_2O only, a larger proportion of TWT was found in the roots than in the shoots and this difference increased with stage. As expected, dry weights of the cotyledons declined with stage.

Dry weights obtained with treatments in Group II were significantly larger than those for Group I discussed above. TWT averaged 1983 mg at Stage 1 and varied from 1830 to 2100 mg for treatments in Group II. By Stage 4, these values increased to an average of 3725 mg and varied from 3580 to 3860 mg. The relative amount of dry weights in roots and shoots varied with time. At Stage 1, about 28 percent and 22 percent of TWT were found in roots and shoots, respectively. By the final sampling, approximately 46 percent of TWT was in the roots with 48 percent in the shoots.

The maximum dry weights were obtained with treatments in Group III which consisted of Ca + Mg, Complete Hoagland Solution and Hoagland-Mg.

The average total dry weights were 2130 and 5423 mg at Stages 1 and 4, respectively. Values for individual treatments ranged from 2070 to 2170 mg at Stage 1; and from 5140 to 5920 mg at Stage 4. The proportions of roots and shoots making up TWT changed with stage. At Stage 1, roots accounted for 32 percent of TWT with shoots accounting for only 20 percent. At Stage 4, approximately 44 percent and 51 percent of TWT were due to roots and shoots, respectively.

DISCUSSION

There were four times or stages of sampling -- pre-emergence, emergence, unifoliate, and second trifoliate stages. On the average, plants emerged on the seventh day after planting although emergence varied from 4 to 12 days. The seedlings were allowed to grow up to the second trifoliate stage which, on the average, occurred at 19 days after planting but ranged from 17 to 31 days for all treatments (see Table 4).

Dry weights of the cotyledons (COWT) declined with time, irrespective of treatment. Average COWT changed from 870 mg at Stage 1 to 300 mg at Stage 4, for an average decline of about 66 percent. McAlister and Krober (1951), working with soybeans grown in the greenhouse and under field conditions, observed that a total decrease in cotyledon dry weight of 70 percent occurred by 28 days after emergence. According to them, this was due primarily to the depletion of organic food reserves -- proteins, fatty acids, and carbohydrates -- and also due to depletion of mineral nutrients. A similar observation was made by Mitchell (1970). In this study, a total loss of about 68 percent of the initial COWT occurred by 19 days after planting which closely agrees with McAlister and Krober (1951).

In addition to the decline in COWT, depletion of most of the nutrients from the cotyledons occurred with time (Table 21). The fourth and seventh columns in Table 21 show the amounts of each nutrient removed from the cotyledons, expressed as a percentage of the initial amounts.

Table 21. Nutrient contents and concentrations of cotyledons at Stages 1 and 4; and amounts depleted from cotyledons expressed as percentage of initial amounts, for selected treatments

Nutrient element	Nutrient content						Nutrient concentration			
	Sampling stage		% depleted	Sampling stage		% depleted	Sampling stage		Sampling stage	
	1	4		1	4		1	4	1	4
	H_2O			Hoagland - (Ca + Mn)			H_2O		Hoagland - (Ca + Mn)	
K[a]	13.0	2.6	80	16.1	8.8	45	1.7	0.9	1.8	2.5
P[a]	4.6	1.4	70	5.9	1.2	80	0.6	0.5	0.7	0.3
Mg[a]	2.8	1.6	43	3.4	1.6	53	0.4	0.6	0.4	0.4
B[b]	14	14	48	31	18	42	31	27	35	48
Mn[b]	29	15	48	36	25	31	37	51	40	69
Ca[a]	2.8	1.7	39	2.3	2.0	13	0.4	0.6	0.3	0.5
	Ca + Mn			Hoagland			Ca + Mn		Hoagland	
K[a]	13.4	1.0	93	20.4	6.6	68	1.6	0.4	2.2	2.3
P[a]	4.6	0.6	87	4.9	0.9	82	0.6	0.2	0.5	0.3
Mg[a]	2.9	1.8	33	3.1	1.4	55	0.3	0.7	0.3	0.5
B[b]	28	16	43	31	11	65	34	63	34	49
Mn[b]	28	17	39	37	15	59	34	67	37	51
Ca[a]	5.7	2.6	54	3.6	3.2	11	0.8	1.0	0.4	1.1

[a]Nutrient content express in mg; concentration in percent of dry weight.

[b]Nutrient content express in μg; concentration in μg/g of dry weight.

Based upon these percentages the nutrients studied could be categorized as follows: 1. highly mobile (P and K); 2. moderately mobile (Mg, B, and Mn); and 3. relatively immobile (Ca). Average depletion for these groups respectively, were 69, 44, and 26 percent when Ca and Mn were absent from solution; and increased slightly to 86, 49, and 33 percent when both nutrients were in solution. Calcium concentrations (but not the amounts of Ca) in the cotyledons increased with stage because the loss in COWT was greater than the loss in Ca content. The concentrations of B, Mg, and Mn in the cotyledons also increased, though not as much as Ca, for the same reason. Growing plants in Hoagland Solution did not restrict the depletion of P and K from the cotyledons but did for Ca. Differences in nutrient contents tended to be associated with the presence or absence of Ca and Mn thus suggesting that other nutrients supplied in Hoagland Solution (Complete or modified) had little or no effect.

Table 22. Average dry weight (mg) of roots and shoots at Stages 1 and 4 and percentage increases in dry weights for selected treatment

Plant portions	Sampling stage 1	Sampling stage 4	%<	Sampling stage 1	Sampling stage 4	%<
	H_2O			Hoagland - (Ca + Mn)		
Root	420	730	67	420	840	100
Shoot	340	700	106	300	1500	400
	Ca + Mn			Hoagland		
Root	450	4000	789	450	2180	384
Shoot	280	1490	432	370	2570	595

Dry weights in the roots (ROWT) and shoots (SHWT) increased with stage for all treatments; these increases were larger with Ca and Mn in solution. Hence, differences among treatments were due primarily to the presence or absence of these two nutrients. Although total dry weights (TWT) obtained with both Ca and Mn in solution was similar whether in water or in Hoagland Solution, there were differences in the proportion of TWT found in the roots and shoots. ROWT was comparatively larger than SHWT with Ca and Mn in water; whereas in Hoagland Solution there was a more even distribution of dry weights between the two portions. These differences in the proportions of dry weights, together with differences obtained with Hoagland - (Ca + Mn), indicate that one or more of the other nutrients supplied in Hoagland Solution influenced more growth of the shoots; whereas Ca and Mn stimulated more root growth (Table 22).

The compositions of various nutrients in the roots and shoots were influenced differently by Ca and Mn in solution. These observations are summarized in Tables 23 and 24 for roots and shoots, respectively. Calcium content in both roots and shoots increased with Ca and Mn in the solution. In terms of the actual amounts of Ca and percentage increases, there were more in the shoots than in the roots. The presence of other nutrients supplied in Hoagland Solution appeared to enhance Ca uptake only slightly. Like Ca, Mn content in roots and shoots increased with time for all treatments. There were larger increases with Ca and Mn in solution. One or more of the other nutrients in Hoagland Solution seemed to enhance Mn accumulation in both roots and shoots. As was for the other

Table 23. Nutrient contents and concentration of roots at Stages 1 and 4; and increases in contents as percentages of initial amounts for selected treatments

Nutrient element	Nutrient content						Nutrient concentration			
	Sampling stage		%	Sampling stage		%	Sampling stage		Sampling stage	
	1	4	increase	1	4	increase	1	4	1	4
	H_2O			Hoagland - (Ca + Mn)			H_2O		Hoagland - (Ca + Mn)	
K[a]	7.0	8.3	19	12.7	45.3	257	1.7	1.2	3.0	5.4
P[a]	2.7	2.6	- 4	2.4	2.1	- 12	0.7	0.4	0.6	0.2
Mg[a]	0.4	0.7	75	0.7	3.1	343	0.1	0.1	0.2	0.4
B[b]	7	9	29	8	15	88	16	13	19	18
Mn[b]	4	11	175	7	9	29	10	14	17	10
Ca[a]	0.3	1.0	233	0.3	1.1	267	0.1	0.1	0.2	0.1
	Ca + Mn			Hoagland			Ca + Mn		Hoagland	
K[a]	6.7	13.3	99	12.7	46.2	264	1.5	0.3	3.8	2.2
P[a]	2.0	3.8	90	1.5	4.0	167	0.4	0.1	0.3	0.2
Mg[a]	0.6	1.1	83	1.1	9.2	736	0.1	0.0	0.3	0.5
B[b]	6	18	200	7	24	243	13	5	16	13
Mn[b]	4	19	375	5	31	520	8	5	10	14
Ca[a]	0.8	7.1	788	1.0	8.2	720	0.2	0.2	0.2	0.4

[a]Nutrient content express in mg; concentration as percent of dry weight.

[b]Nutrient content express in μg; concentraiton as μg/g of dry weight.

Table 24. Nutrient contents and concentrations of shoots at Stages 1 and 4; and increases in contents expressed as percentage of initial amounts for selected treatments

Nutrient element	Nutrient content: Sampling stage 1	Sampling stage 4	% depleted	Sampling stage 1	Sampling stage 4	% depleted	Nutrient concentration: Sampling stage 1	Sampling stage 4	Sampling stage 1	Sampling stage 4
	H_2O			Hoagland - (Ca + Mn)			H_2O		Hoagland - (Ca + Mn)	
K[a]	7.2	9.6	33	9.1	58.2	649	2.1	1.3	3.0	4.6
P[a]	2.1	2.9	38	2.5	5.9	136	0.6	0.4	0.8	0.4
Mg[a]	0.6	1.4	133	1.0	8.3	730	0.2	0.2	0.3	0.6
B[b]	11	20	82	12	41	242	31	27	40	28
Mn[b]	6	15	150	9	29	222	19	21	31	18
Ca[a]	0.2	0.8	300	0.3	1.3	333	0.1	0.1	0.1	0.1
	Ca + Mn			Hoagland			Ca + Mn		Hoagland	
K[a]	5.8	12.2	110	12.7	74.8	489	2.1	0.5	3.5	3.0
P[a]	1.9	4.5	137	2.9	11.8	307	0.7	0.3	0.8	0.4
Mg[a]	0.6	1.7	183	1.0	8.6	760	0.2	0.1	0.3	0.3
B[b]	9	21	133	12	83	592	32	14	31	27
Mn[b]	7	27	286	8	83	938	27	19	19	21
Ca[a]	0.6	11.7	1850	1.4	20.0	1329	0.2	0.8	0.4	0.9

[a]Nutrient content expressed in Mg; concentration in percent of dry weight.

[b]Nutrient content expressed in μg; concentration in μg/g of dry weight.

nutrients, there was significantly more Mn in the shoots than in the roots for all treatments (Tables 23 and 24). We do not have a logical explanation for this occurrence which was similar to the findings of Jones and Lunt (1967). They reported that in both mono- and dicotyledons the roots ordinarily contain significantly less calcium and most other nutrients than do the tops.

The amounts of P and K in the cotyledons appeared to be adequate for plant growth because supplying them did not materially alter plant growth. There was greater uptake of K and less of P when both were present in solution. Because Hoagland Solution applied P and K, there was some uptake of both nutrients. Accumulation of K in both roots and shoots and of P in the shoots was enhanced when Ca and Mn were in solution. There was no real increase in the amount of P in the roots. The amounts of both K and P were larger in the shoots than in the roots. Magnesium content increased with stage in both roots and shoots. The amount of Mg increased as a result of magnesium in the Hoagland Solution. However, while Mg content of the shoots did not appear to be influenced much by Ca and Mn in Hoagland Solution, the Mg content of the roots was greatly influenced increasing from 2.1 to 9.2 mg.

SUMMARY AND CONCLUSIONS

In this greenhouse study, we investigated the effects of different nutrient solutions on soybean seedling growth and development. The underlying hypothesis was that although seeds generally contain adequate amounts of most nutrients that are essential for the early growth and development of emerging seedlings, they are often low or deficient in certain nutrients, for one reason or another. We hypothesize further that these deficiencies adversely affect, restrict, or in extreme cases, prevent seedling growth and development. Subsequently, it was further hypothesized that supplying the deficient nutrients in the growth environment can and do enhance seedling growth and development.

The major objectives of this study were to investigate:

(1) The quantitative and qualitative relationships between various nutrient solutions and developing soybean seedlings.

(2) The effects of these nutrient solutions on the dry weights and chemical composition of roots, shoots, and cotyledons of developing seedlings. In particular, to study the effects of different nutrient solutions on the accumulation and redistribution of dry matter and nutrients in each plant part studied.

(3) Which nutrients are more crucial for the early development of soybean seedlings.

(4) The period during which these nutrients are needed the most by the seedlings.

For this purpose, seedlings were sampled at four stages -- pre-emergence, emergence, unifoliate stage and second trifoliate stage. In our investigation, these stages on the average occurred at approximately 1, 7, 12, and 19 days after planting, respectively. At each stage or time of sampling the plants were washed with deionized water until free of sand particles and then partitioned into three parts: roots, shoots, and cotyledons. The samples were oven-dried and weighed. In two out of seven experiments, the samples were ground and then analyzed for P, K, Ca, Mg, Mn, B, Fe, Na, Cu, Zn and Al. In the remaining five experiments, only dry weight data were collected.

The combined results of all seven experiments showed that dry weights in the cotyledons decreased irrespective of treatment; conversely, dry weights of roots and shoots increased with stage and as a result of treatment. These increases were due primarily to Ca and to a lesser extent to Mn. When both Ca and Mn were supplied together in water, total dry weights obtained were similar to Complete Hoagland Solution, but root weight was larger than shoot weight. There was a more even distribution of dry weights due to Hoagland Solution.

Depletion of most nutrients from the cotyledons occurred. However, as the rate of Ca depletion was less than that for other nutrients and since cotyledon dry weights also decreased; there was a rise in Ca concentration in the cotyledons with time. There was a similar increase in Mg concentration, though not as much.

Variations in nutrient contents of roots and shoots were influenced by their presence or absence in the nutrient solutions. These differences were modified by the presence or absence of Ca and Mn in solution. Nutrient contents were generally higher in the shoots than in the roots, whether or not Ca and Mn were present in solution. These differences in nutrient contents were consistent with differences in dry weights of each plant portion.

These results show that there were substantial differences among soybean seedlings treated with different nutrient solutions, the differences being due to Ca and Mn. In general, solutions containing Ca and Mn, whether in H_2O or Hoagland Solution, favorably influenced seedling dry weight and the nutrient contents of the roots and shoots. Treatments did not seem to affect nutrient content of the cotyledons. The intervals between the unifoliate stage and the second trifoliate stage (Stages 3 and 4) appeared to be the period during which treatment effects were more prominant. This suggests that the seeds did not contain or could not supply adequate amounts of Ca and Mn for normal development of soybean seedlings. Also, that these deficiencies were more crucial from the unifoliate stage to the second trifoliate stage when the last sampling was done.

Finally, this study was a very interesting and challenging one but also one that was plagued by many problems. We have succeeded in answering some question about how the soybean seed and its contents influence the developing soybean plant; and how these relationships are altered by supplying certain nutrients in the growth environment. However, we have discovered that our knowledge in this area is, at best, very limited.

In this study, we were unable to determine with a high degree of certainty, the changes occurring during the pre-emergence and emergence periods of seedling development. Additional studies are recommended to solve the unanswered questions and to study in greater detail the transformations occurring during the first two phases. Lastly, we recommend that further research in this area is needed to help us understand why certain seeds germinate and others do not; why vast differences occur among seeds even seeds from the same batch; whether there are and what relationships exist between the mother plant and the resulting seeds.

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APPENDIX A: TABLES OF MEANS

Table A-1. Average dry weight of roots (ROWT), shoots (SHWT), cotyledons (COWT), and of total plants (TWT) of soybean seedlings treated with different nutrient solutions -- Ca-Mn-Hoagland Experiment I

Sampling stage	Treatment: Water solutions H_2O	Ca	Mn	Ca + Mn	Hoagland solutions Complete	-Ca	-Mn	-(Ca + Mn)
				ROWT (mg/9 plants)				
1	420	380	340	450	450	400	440	420
2	490	610	540	550	700	570	780	610
3	750	1310	1020	2710	1710	1100	2050	900
4	730	1960	1260	4000	2180	1460	3590	840
				SHWT (mg/9 plants)				
1	340	290	290	280	370	300	290	300
2	400	330	350	380	510	390	510	470
3	690	940	820	1160	1850	1560	1960	1360
4	700	1350	890	1490	2570	1820	2250	1500
				COWT (mg/9 plants)				
1	780	920	810	800	930	960	880	900
2	660	670	630	600	670	610	590	580
3	340	390	330	340	370	400	300	460
4	280	310	330	260	290	320	240	370
				TWT (mg/9 plants)				
1	1540	1590	1440	1530	1750	1660	1610	1620
2	1550	1610	1520	1430	1880	1570	1880	1660
3	1780	2640	2170	4210	3830	3060	4310	2720
4	1710	3620	2480	5750	5040	3600	6080	2710

Table A-2. Average P content in roots (PRO), in shoots (PSH), in cotyledons (PCO), and in total plant (TP) of soybean seedlings treated with different nutrient solutions -- Ca-Mn-Hoagland Experiment I

Sampling stage	Treatment							
	Water solutions				Hoagland solutions			
	H_2O	Ca	Mn	Ca + Mn	Complete	-Ca	-Mn	-(Ca + Mn)
				PRO (mg)				
1	2.7	1.6	2.2	2.0	1.5	2.1	2.2	2.4
2	3.1	2.6	2.9	2.8	1.3	2.9	2.3	2.2
3	2.8	2.4	3.3	3.2	1.9	2.2	2.3	2.1
4	2.6	2.6	4.2	3.8	4.0	2.4	2.7	2.1
				PSH (mg)				
1	2.1	2.0	2.0	1.9	2.9	2.5	2.1	2.5
2	2.6	2.1	2.2	2.4	1.9	3.1	3.6	3.2
3	3.2	3.1	3.6	4.3	7.1	6.8	8.3	6.6
4	2.9	4.3	3.6	4.5	11.8	6.1	8.3	5.9
				PCO (mg)				
1	4.6	5.2	4.4	4.6	4.9	6.2	4.9	5.9
2	3.9	3.4	3.4	3.4	2.8	3.6	2.7	3.0
3	1.6	1.2	1.4	1.1	1.0	1.7	0.7	1.6
4	1.4	0.9	1.4	0.6	0.9	1.3	0.5	1.2
				TP (mg)				
1	9.4	8.8	8.6	8.5	9.3	10.8	9.2	10.8
2	9.6	8.1	8.5	8.6	6.0	9.6	8.6	8.4
3	7.6	6.7	8.3	8.6	10.0	10.7	11.3	10.3
4	6.9	7.8	7.2	8.9	15.7	9.8	11.5	9.2

Table A-3. Average K content in roots (KRO), in shoots (KSH), in cotyledons (KCO), and in total plant (TK) of soybean seedlings treated with different nutrient solutions -- Ca-Mn-Hoagland Experiment I

Sampling stage	Treatment							
	Water solutions				Hoagland solutions			
	H_2O	Ca	Mn	Ca + Mn	Complete	-Ca	-Mn	-(Ca + Mn)
				KRO (mg)				
1	7.0	5.7	6.8	6.7	12.7	14.4	9.9	12.7
2	9.2	8.8	7.6	7.9	12.5	17.3	12.9	22.2
3	8.2	9.2	10.6	11.1	30.0	42.8	22.3	45.6
4	8.3	10.1	13.3	13.3	46.2	54.5	31.1	45.3
				KSH (mg)				
1	7.2	6.5	6.8	5.8	12.7	10.0	6.4	9.1
2	9.0	7.0	7.2	7.1	15.0	12.7	13.7	18.0
3	10.4	8.9	11.5	12.0	52.4	61.4	43.9	59.3
4	9.6	12.5	11.6	12.2	74.8	73.4	63.1	68.2
				KCO (mg)				
1	13.0	14.2	8.5	13.4	20.4	17.2	12.7	16.1
2	11.7	9.7	7.9	8.5	16.2	12.5	10.2	14.3
3	3.9	2.9	2.6	2.0	10.2	13.8	3.7	10.7
4	2.6	2.0	2.8	1.0	6.6	11.9	2.8	8.8
				TK (mg)				
1	27.2	26.4	22.1	25.9	45.8	41.6	29.0	37.9
2	29.9	25.5	22.7	23.5	43.7	42.5	36.8	54.5
3	22.5	21.0	24.7	25.1	92.6	118.0	69.9	115.6
4	20.5	24.6	27.7	26.5	127.6	139.8	97.0	122.3

Table A-4. Average Ca content in roots (CaRO), in shoots (CaSH), in cotyledons (CaCO), and in total plant (TCa) of soybean seedlings treated with different nutrient solutions -- Ca-Mn-Hoagland Experiment I

Sampling stage	Treatment							
	Water solutions				Hoagland solutions			
	H_2O	Ca	Mn	Ca + Mn	Complete	-Ca	-Mn	-(Ca + Mn)
				CaRO (mg)				
1	0.3	0.5	0.3	0.8	1.0	0.5	0.7	0.3
2	0.4	1.2	0.4	1.7	2.5	0.5	2.5	0.5
3	0.5	2.4	0.7	4.1	6.4	0.8	6.2	0.7
4	1.0	5.1	1.6	7.1	8.2	1.3	9.5	1.1
				CaSH (mg)				
1	0.2	0.5	0.2	0.6	1.4	0.4	0.7	0.3
2	0.3	0.8	0.3	1.2	5.2	0.5	3.3	0.5
3	0.6	5.6	0.8	8.2	20.3	1.5	19.7	0.9
4	0.8	9.9	1.4	11.7	20.8	1.7	27.3	1.3
				CaCO (mg)				
1	2.8	2.9	2.7	5.7	3.6	3.1	2.7	2.3
2	2.5	2.4	2.3	4.1	4.6	2.1	3.0	2.7
3	1.8	2.4	2.2	3.4	4.9	2.4	2.7	2.8
4	1.7	2.7	2.1	2.6	3.2	2.3	3.4	2.0
				TCa (mg)				
1	3.3	3.9	3.2	7.1	6.0	4.0	4.1	2.9
2	3.2	4.4	3.0	7.0	12.3	3.1	8.8	3.7
3	2.9	10.4	3.7	15.7	31.6	5.7	28.6	4.4
4	3.5	17.7	5.1	21.4	32.2	5.3	40.2	4.4

Table A-5. Average Mg content in roots (MgRO), in shoots (MgSH), in cotyledons (MgCO), and in total plant (TMg) of soybean seedlings treated with different solutions -- Ca-Mn-Hoagland Experiment I

Sampling stage	Treatment							
	Water solutions				Hoagland solutions			
	H_2O	Ca	Mn	Ca + Mn	Complete	-Ca	-Mn	-(Ca + Mn)
				MgRO (mg)				
1	0.4	0.3	0.4	0.6	1.1	0.8	1.1	0.7
2	0.5	0.6	0.4	0.6	3.0	1.1	3.3	1.3
3	0.4	0.6	0.5	0.8	8.2	2.9	8.0	3.0
4	0.7	0.9	0.8	1.0	9.2	4.0	10.0	3.1
				MgSH (mg)				
1	0.6	0.7	0.6	0.6	1.0	0.9	0.8	1.0
2	0.8	0.7	0.8	0.6	1.4	1.8	1.6	2.3
3	1.3	1.4	1.7	1.7	5.7	8.2	6.6	7.3
4	1.4	1.7	2.2	1.7	8.6	10.1	8.6	8.3
				MgCO (mg)				
1	2.8	3.0	2.9	2.7	3.1	3.6	3.1	3.4
2	2.5	2.3	2.5	2.6	3.0	2.5	2.8	2.5
3	1.7	2.0	2.0	2.2	2.3	2.9	1.7	2.5
4	1.6	2.0	2.1	1.8	1.4	2.5	2.1	1.6
				TMg (mg)				
1	3.8	4.0	3.9	3.9	4.2	5.3	5.0	5.1
2	3.8	3.6	3.7	3.8	7.4	5.4	7.7	6.1
3	3.4	4.0	4.2	4.7	16.2	14.0	16.3	12.8
4	3.7	4.6	5.1	4.6	19.2	16.6	20.7	13.0

Table A-6. Average Mn content in roots (MnRO), in shoots (MnSH), in cotyledons (MnCO), and in total plants (TMn) of soybean seedlings treated with different nutrient solutions -- Ca-Mn-Hoagland Experiment I

Sampling stage	Treatment							
	Water solutions				Hoagland solutions			
	H_2O	Ca	Mn	Ca + Mn	Complete	-Ca	-Mn	-(Ca + Mn)
				MnRO (μg)				
1	4	3	7	4	5	7	6	7
2	6	6	9	4	7	7	7	5
3	7	10	14	11	14	9	10	7
4	11	11	17	19	31	12	30	9
				MnSH (μg)				
1	6	6	7	7	8	10	9	9
2	8	9	10	10	10	12	15	15
3	15	17	28	21	43	36	29	25
4	15	27	27	27	83	33	40	28
				MnCO (μg)				
1	29	28	35	28	37	42	35	36
2	23	28	32	26	35	30	26	24
3	17	20	22	20	28	23	18	22
4	15	19	19	17	15	23	22	25
				TMn (μg)				
1	39	37	49	39	50	59	50	52
2	37	43	51	40	52	49	48	44
3	39	47	64	52	85	68	57	54
4	41	57	63	63	129	68	92	62

Table A-7. Average B content in roots (BRO), in shoots (BSH), in cotyledons (BCO), and in total plants (TB) of soybean seedlings treated with different nutrient solutions -- Ca-Mn-Hoagland Experiment I

Sampling stage	Treatment							
	Water solutions				Hoagland solutions			
	H_2O	Ca	Mn	Ca + Mn	Complete	-Ca	-Mn	-(Ca + Mn)
				BRO (μg)				
1	7	5	6	6	7	8	8	8
2	8	8	7	7	9	11	12	9
3	9	11	10	15	18	16	20	14
4	9	15	14	18	24	21	25	15
				BSH (μg)				
1	11	9	9	9	12	11	10	12
2	13	10	11	11	15	14	16	14
3	21	14	22	20	47	44	55	40
4	20	21	21	21	83	46	70	41
				BCO (μg)				
1	27	29	28	28	31	35	31	31
2	23	23	24	24	28	23	25	24
3	16	19	20	18	16	20	16	26
4	14	18	17	16	11	21	18	18
				TB (μg)				
1	45	42	42	43	50	54	49	51
2	44	41	42	42	42	48	53	47
3	46	44	52	53	81	80	91	70
4	43	54	52	55	118	88	113	74

Table A-8. Average dry weight of roots (ROWT), shoots (SHWT), cotyledons (COWT), and of total plants (TWT) of soybean seedlings treated with different nutrient solutions -- B-Hoagland Experiment I

Sampling stage	Treatment: Water solutions H_2O	Treatment: Water solutions B	Treatment: Hoagland solutions Complete	Treatment: Hoagland solutions -B
	ROWT (mg/9 plants)			
1	420	420	450	600
2	490	560	700	740
3	750	780	1710	2230
4	730	1390	2180	2840
	SHWT (mg/9 plants)			
1	340	270	370	280
2	400	360	510	470
3	690	750	1850	1370
4	700	1030	2570	2640
	COWT (mg/9 plants)			
1	780	830	930	900
2	660	590	670	720
3	340	360	370	340
4	280	260	290	290
	TWT (mg/9 plants)			
1	1540	1520	1750	1780
2	1550	1510	1880	1930
3	1780	1890	3930	3940
4	1710	2680	5040	5770

Table A-9. Average P content in roots (PRO), in shoots (PSH), in cotyledons (PCO), and in total plant (TP) of soybean seedlings treated with different nutrient solutions -- B-Hoagland Experiment I

Sampling stage	Treatment: Water solutions H_2O	Water solutions B	Hoagland solutions Complete	Hoagland solutions -B
		PRO (mg)		
1	2.7	2.3	1.5	2.2
2	3.1	3.0	1.3	2.6
3	2.8	3.3	1.9	2.2
4	2.6	3.5	4.0	2.6
		PSH (mg)		
1	2.1	2.1	2.9	0.9
2	2.6	2.4	1.9	3.3
3	3.2	3.8	7.1	5.4
4	2.9	4.2	11.8	8.3
		PCO (mg)		
1	4.6	5.5	4.9	5.2
2	3.9	3.7	2.8	3.6
3	1.6	1.6	1.0	1.0
4	1.4	0.8	0.9	0.4
		TP (mg)		
1	9.4	9.9	9.3	8.3
2	9.6	9.1	6.0	9.5
3	7.6	8.7	10.0	8.6
4	6.9	8.5	15.7	11.3

Table A-10. Average K content in roots (KRO), in shoots (KSH), in cotyledons (KCO), and in total plant (TK) of soybean seedlings treated with different nutrient solutions -- B-Hoagland Experiment I

Sampling stage	Treatment: Water solutions H_2O	Water solutions B	Hoagland solutions Complete	Hoagland solutions -B
		KRO (mg)		
1	7.0	5.6	12.7	11.3
2	9.2	8.2	12.5	11.3
3	8.2	9.3	30.0	23.7
4	8.3	11.2	46.2	25.5
		KSH (mg)		
1	7.2	6.0	12.7	2.5
2	9.0	6.8	15.0	11.7
3	10.4	10.6	52.4	31.7
4	9.6	12.3	74.8	55.3
		KCO (mg)		
1	13.0	14.0	20.4	15.6
2	11.7	8.8	16.2	11.5
3	3.9	3.1	10.2	5.5
4	2.6	1.4	6.6	3.5
		TK (mg)		
1	27.2	25.6	45.8	29.4
2	29.9	23.8	43.7	34.5
3	22.5	23.0	92.6	60.9
4	20.5	24.9	127.6	84.3

Table A-11. Average Ca content in roots (CaRO), in shoots (CaSH), in cotyledons (CaCO), and in total plant (TCa) of soybean seedlings treated with different nutrient solutions -- B-Hoagland Experiment I

Sampling stage	Treatment: Water solutions		Treatment: Hoagland solutions	
	H_2O	B	Complete	-B
		CaRO (mg)		
1	0.3	0.3	1.0	1.0
2	0.4	0.4	2.5	1.5
3	0.5	0.6	6.4	7.2
4	1.0	1.0	8.2	8.2
		CaSH (mg)		
1	0.2	0.2	1.4	0.3
2	0.3	0.3	5.2	2.3
3	0.6	0.7	20.3	14.1
4	0.8	1.0	20.8	27.0
		CaCO (mg)		
1	2.8	2.9	3.6	3.0
2	2.5	2.6	4.6	4.6
3	1.8	2.4	4.9	4.2
4	1.7	2.3	3.2	3.9
		TCa (mg)		
1	3.3	3.4	6.0	4.3
2	3.2	3.3	12.3	8.4
3	2.9	3.7	31.6	25.5
4	3.5	4.3	32.2	39.1

Table A-12. Average Mg content in roots (MgRO), in shoots (MgSH), in cotyledons (MgCO), and in total plant (TMg) of soybean seedlings treated with different nutrient solutions -- B-Hoagland Experiment I

	Treatment			
	Water solutions		Hoagland solutions	
Sampling stage	H_2O	B	Complete	-B
		MgRO (mg)		
1	0.4	0.4	1.1	1.0
2	0.5	0.6	3.0	1.5
3	0.4	0.5	8.2	8.0
4	0.7	0.7	9.2	6.8
		MgSH (mg)		
1	0.6	0.6	1.0	0.3
2	0.8	0.8	1.4	1.3
3	1.3	1.5	5.7	4.6
4	1.4	2.0	8.6	8.3
		MgCO (mg)		
1	2.8	3.1	3.1	2.9
2	2.5	2.6	3.0	2.5
3	1.7	2.2	2.3	2.3
4	1.6	1.8	1.4	2.2
		TMg (mg)		
1	3.8	4.1	4.2	4.2
2	3.8	4.0	7.4	5.3
3	3.4	4.2	16.2	14.9
4	3.7	4.5	19.2	17.3

Table A-13. Average Mn content in roots (MnRO), in shoots (MnSH), in cotyledons (MnCO), and in total plants (TMn) of soybean seedlings treated with different nutrient solutions -- B-Hoagland Experiment I

Sampling stage	Treatment			
	Water solutions		Hoagland solutions	
	H_2O	B	Complete	-B
	MnRO (μg)			
1	4	5	5	5
2	6	6	7	7
3	7	9	14	11
4	11	12	31	10
	MnSH (μg)			
1	6	6	8	7
2	8	8	10	14
3	15	17	43	33
4	15	22	83	50
	MnCO (μg)			
1	29	29	37	33
2	23	24	35	28
3	17	19	28	29
4	15	19	15	23
	TMn (μg)			
1	39	40	50	41
2	37	38	52	49
3	39	45	85	73
4	41	53	129	83

Table A-14. Average B content in roots (BRO), in shoots (BSH), in cotyledons (BCO), and in total plants (TB) of soybean seedlings treated with different nutrient solutions -- B-Hoagland Experiment I

Sampling stage	Treatment: Water solutions H_2O	Treatment: Water solutions B	Treatment: Hoagland solutions Complete	Treatment: Hoagland solutions -B
		BRO (μg)		
1	7	5	7	7
2	8	7	9	8
3	9	9	18	14
4	9	13	24	18
		BSH (μg)		
1	11	9	12	3
2	13	10	15	15
3	21	20	47	20
4	20	25	83	29
		BCO (μg)		
1	27	28	31	31
2	23	25	28	25
3	16	18	16	21
4	14	17	11	18
		TB (μg)		
1	45	42	50	41
2	44	42	42	48
3	46	47	81	55
4	43	55	118	65

Table A-15. Average dry weights of roots (ROWT), shoots (SHWT), cotyledons (COWT), and of total plants (TWT) of soybean seedlings treated with different nutrient solutions -- Ca-Mn-Experiment II

Sampling stage	Treatment							
	Water solutions				Hoagland solutions			
	H_2O	Ca	Mn	Ca + Mn	Complete	-Ca	-Mn	-(Ca + Mn)
				ROWT (mg/9 plants)				
1	130	410	240	540	330	520	290	250
2	170	1000	660	1320	890	620	790	440
3	150	1030	840	2090	1050	650	930	790
4	110	1940	910	2620	1750	880	1150	860
				SHWT (mg/9 plants)				
1	170	600	610	640	300	320	290	270
2	260	1140	710	800	950	630	370	670
3	270	1390	960	1760	2350	1160	1520	1130
4	170	1790	1330	1930	250	1650	2220	2020
				COWT (mg/9 plants)				
1	940	940	860	940	860	660	900	910
2	620	440	390	410	510	380	720	370
3	310	260	380	320	290	360	290	240
4	110	110	300	210	190	150	150	170
				TWT (mg/9 plants)				
1	1240	1950	1710	2120	1490	1500	1480	1430
2	1050	2580	1760	2530	2350	1630	1880	1480
3	830	2680	2170	4170	3690	2170	2740	2260
4	500	3830	2540	4760	4420	2680	3520	3050

Table A-16. Average dry weights of roots (ROWT), shoots (SHWT), cotyledons (COWT), and of total plants (TWT) of soybean seedlings treated with different nutrient solutions -- Ca-Mn-Hoagland Experiment II

Sampling stage	Treatment							
	Water solutions				Hoagland solutions			
	H_2O	Ca	Mn	Ca + Mg	Complete	-Ca	-Mg	-(Ca + Mg)
				ROWT (mg/9 plants)				
1	130	410	360	280	330	520	310	290
2	170	1000	470	610	890	620	500	650
3	150	1030	550	510	1050	650	720	850
4	110	1940	900	900	1730	880	870	920
				SHWT (mg/9 plants)				
1	170	600	300	270	300	320	310	260
2	260	1140	530	510	950	630	450	560
3	270	1390	640	810	2350	1160	740	780
4	170	1780	790	1350	2500	1650	970	1050
				COWT (mg/9 plants)				
1	940	940	800	750	860	660	710	880
2	620	440	660	410	510	380	480	450
3	310	260	320	360	290	360	400	350
4	110	110	240	180	190	150	300	160
				TWT (mg/9 plants)				
1	1240	1950	1460	1300	1490	1500	1330	1430
2	1050	2580	1660	1530	2350	1630	1430	1660
3	830	2680	1510	1680	3690	2170	1860	1980
4	500	3830	1930	2430	4420	2680	2140	2130

Table A-17. Average dry weights of roots (ROWT), shoots (SHWT), cotyledons (COWT), and of total plants (TWT) of soybean seedlings treated with different nutrient solutions -- Ca-Mn-Hoagland Experiment III

Sampling stage	Treatment							
	Water solutions				Hoagland solutions			
	H_2O	Ca	Mn	Ca + Mn	Complete	-Ca	-Mn	-(Ca + Mn)
	ROWT (mg/9 plants)							
1	700	680	640	720	560	630	870	440
2	930	910	900	940	1050	970	1200	910
3	1140	1290	1280	1760	1350	1180	1480	1120
4	1080	1870	2020	2100	2150	1920	2580	1550
	SHWT (mg/9 plants)							
1	360	430	360	410	490	560	420	380
2	460	780	420	600	700	980	760	570
3	670	1350	960	1280	1870	1280	1540	1260
4	620	1620	2010	1950	3470	1610	2380	1650
	COWT (mg/9 plants)							
1	1070	990	1050	1000	1020	770	1030	1020
2	740	720	930	770	740	750	800	870
3	380	440	510	450	480	520	450	530
4	160	310	240	200	300	330	180	310
	TWT (mg/9 plants)							
1	2130	2100	2050	2130	2070	1960	2320	1840
2	2130	2410	2250	2310	2590	2700	2760	2350
3	2190	3080	2750	3500	3700	2980	3470	2910
4	1860	3800	4270	4250	5920	3860	5140	3510

Table A-18. Average dry weights of roots (ROWT), shoots (SHWT), cotyledons (COWT), and of total plants (TWT) of soybean seedlings treated with different nutrient solutions -- B-Hoagland Experiment III

Sampling stage	Treatment: Water solutions H_2O	Treatment: Water solutions B	Treatment: Hoagland solutions Complete	Treatment: Hoagland solutions -B
		ROWT (mg/9 plants)		
1	700	660	560	640
2	930	970	1050	930
3	1140	1280	1350	1220
4	1080	1660	2150	1630
		SHWT (mg/9 plants)		
1	360	360	490	410
2	460	540	700	670
3	670	770	1870	1590
4	620	1280	3470	2900
		COWT (mg/9 plants)		
1	1070	1110	1020	1100
2	740	710	740	800
3	380	570	480	500
4	160	320	300	190
		TWT (mg/9 plants)		
1	2130	2130	2070	2150
2	2130	2220	2590	2490
3	2190	2620	3700	3300
4	1860	3260	5920	4720

Table A-19. Average dry weights of roots (ROWT), shoots (SHWT), cotyledons (COWT), and of total plants (TWT) of soybean seedlings treated with different nutrient solutions -- Ca-Mg-Hoagland Experiment III

Sampling stage	Treatment: Water solutions H_2O	Ca	Mg	Ca + Mg	Hoagland solutions Complete	-Ca	-Mg	-(Ca + Mg)
				ROWT (mg/9 plants)				
1	700	680	480	690	560	630	780	460
2	930	910	870	1120	1050	970	1140	740
3	1140	1290	1040	1810	1350	1180	1700	1120
4	1080	1870	1590	2050	2150	1920	2920	1830
				SHWT (mg/9 plants)				
1	360	430	320	470	490	560	390	450
2	460	780	540	560	700	980	570	680
3	670	1350	1690	1390	1870	1290	1160	1510
4	620	1620	2810	2920	3470	1610	2940	2510
				COWT (mg/9 plants)				
1	1070	990	1030	900	1020	770	1000	1130
2	740	720	900	760	740	750	840	710
3	380	440	580	520	480	520	440	450
4	160	310	260	340	300	330	280	240
				TWT (mg/9 plants)				
1	2130	2100	1830	2150	2070	1960	2170	2040
2	2130	2410	2310	2440	2590	2700	2550	2130
3	2190	3080	3310	3720	3700	2980	3300	3080
4	1860	3800	4660	5210	5920	3860	6140	4580

APPENDIX B: EXPERIMENTAL DATA

NOTE: The following notations are used in all Appendix B tables.

I. Dry weights are given in mg/9 plants.

II. Nutrient contents are expressed in mg for P, K, Ca, and Mg; and in µg for all other nutrients.

III. Nutrient concentrations are expressed as percentage of dry weights for P, K, Ca, and Mg; and as µg/g for all other nutrients.

IV. Treatments are represented by numbers as follows:

Trt. No.	Description
1	Complete Hoagland
2	Ca + Mn
3	Ca alone
4	Mn alone
5	Hoagland-Ca
6	Hoagland-Mn
7	Hoagland - (Ca + Mn)
8	B alone
9	Hoagland-B
10	H_2O (deionized)
11	Hoagland-Mg
12	Ca + Mn
13	Hoagland - (Ca + Mn)
14	Mg alone

Table B-1. Dry weights and nutrient concentrations of whole seedlings and portions thereof for soybean seedlings treated with different nutrient solutions

TRT	REP	STAGE	ROWT	SHWT	COWT	PRO	PSH	PCO	KRO	KSH	KCO
1	1	1	650	520	960	3332	7823	5423	27970	34678	22277
1	2	1	320	311	1140	3130	7822	5223	28780	34680	22115
1	3	1	390	270	680	3132	7820	5324	27790	34677	21270
1	1	2	680	460	870	1797	3711	4109	17615	29206	24171
1	2	2	890	550	690	1820	3800	4190	17742	29904	23996
1	3	2	520	510	460	1900	3699	4156	18902	29511	24041
1	1	3	2190	2370	360	956	3431	2409	12830	26088	28510
1	2	3	2040	1860	410	1204	4150	3002	17049	28767	29314
1	3	3	890	1320	330	1423	4234	2845	30238	31680	24887
1	1	4	2700	3370	330	2860	6545	3513	22670	25372	21283
1	2	4	2410	2280	300	1064	3265	3086	17656	33361	26142
1	3	4	1430	2070	230	1111	2851	3143	24295	30393	21148
2	1	1	500	300	1030	4543	6736	5624	14364	20449	16654
2	2	1	530	280	860	4360	6588	5692	15762	20015	18215
2	3	1	330	260	510	3720	6920	5820	13979	21248	14289
2	1	2	620	420	700	5056	6365	5775	16104	19649	14436
2	2	2	580	380	700	5132	6280	5629	14315	18467	15280
2	3	2	450	330	400	5287	6428	5701	11896	18236	11896
2	1	3	2970	1440	410	1006	3435	3346	3106	10286	5839
2	2	3	2980	1190	350	1221	4142	3158	4177	11184	7314
2	3	3	2180	840	250	1415	3706	3497	5314	9257	4289
2	1	4	4110	1920	300	830	2696	2249	3253	7296	3489
2	2	4	4490	1370	260	983	3620	2416	2971	9975	4011
2	3	4	3410	1180	220	1079	2813	2651	3856	7469	3579
3	1	1	330	330	1120	4294	6946	5640	14270	22501	15517
3	2	1	350	210	1200	4204	6887	5602	16141	23082	15760
3	3	1	460	330	430	4430	7011	5664	14728	21467	14821
3	1	2	490	260	960	4736	6775	5300	14941	21066	14582
3	2	2	800	370	650	4162	5987	4680	15361	21202	13688
3	3	2	550	370	410	3998	6128	4760	12486	20654	14951
3	1	3	1200	1330	530	1751	2960	3331	8091	8734	7670

Table B-1. Continued

TRT	REP	STAGE	ROWT	SHWT	COWT	PRO	PSH	PCO	KRO	KSH	KCO
3	2	3	920	680	390	2743	3785	3030	8972	9694	7299
3	3	3	1810	800	250	1478	3578	2760	5253	10579	6950
3	1	4	2030	1720	370	1625	2862	3009	6572	9623	5848
3	2	4	1620	1420	350	1036	3297	2963	2914	8571	5298
3	3	4	2220	910	220	1280	3487	2739	5459	9560	8348
4	1	1	330	330	910	6358	6729	5398	19373	22539	14558
4	2	1	300	270	860	6419	6920	5308	18997	22834	12879
4	3	1	390	270	660	6580	7114	5424	21430	25342	1836
4	1	2	600	330	900	5230	6370	5400	15957	19951	13776
4	2	2	540	390	600	5823	6188	5520	12873	20145	11432
4	3	2	470	330	400	5312	6097	5087	13140	21363	10988
4	1	3	1360	1070	370	1826	4030	3990	6082	13090	7460
4	2	3	1000	800	400	4239	5045	4632	13559	16280	8239
4	3	3	690	590	220	4500	4314	4140	14539	12834	7952
4	1	4	1390	1270	360	1707	3778	4172	7036	14301	8510
4	2	4	990	680	390	5876	5319	4479	18839	15445	8480
4	3	4	1390	730	230	3103	3251	4087	8299	8310	8297
5	1	1	360	240	1020	5250	8018	6437	32661	34202	18187
5	2	1	370	280	1130	5187	8441	6521	30833	34001	18265
5	3	1	470	370	740	5362	8316	6288	29762	33241	16728
5	1	2	460	400	810	5536	8794	6365	27932	32201	17868
5	2	2	560	370	620	4963	7960	5762	30437	32044	23640
5	3	2	690	400	400	4816	7281	5301	31780	33145	20953
5	1	3	1200	2300	400	1954	3814	4147	36288	34843	32414
5	2	3	960	1040	520	2056	5554	4218	36412	44963	35123
5	3	3	1130	1340	280	1931	4444	4456	44111	42845	36240
5	1	4	1660	2360	330	1257	2858	3681	28749	43117	29110
5	2	4	1370	1620	400	1661	4412	4883	37949	40485	38535
5	3	4	1340	1490	240	2042	3043	3260	47663	36346	43926
6	1	1	420	350	1070	5356	7541	5761	20168	23125	14567
6	2	1	450	250	890	5050	7033	5255	22319	21463	13572

Table B-1. Continued

TRT	REP	STAGE	ROWT	SHWT	COWT	PRO	PSH	PCO	KRO	KSH	KCO
6	3	1	450	280	680	4938	6942	5586	24794	20586	15550
6	1	2	960	680	650	3422	7058	5217	18169	29774	16484
6	2	2	590	420	720	2214	7143	3992	14381	26415	18271
6	3	2	800	430	410	2760	7001	4361	16152	22992	16152
6	1	3	2010	2290	360	970	3853	1924	7489	21062	10342
6	2	3	2040	2140	290	1268	4661	2863	12968	22757	11397
6	3	3	2100	1440	260	1138	4150	2714	12112	24105	15301
6	1	4	3200	2380	240	734	3435	1960	8904	27698	12848
6	2	4	5310	2470	250	529	3844	1842	5067	28077	11762
6	3	4	2250	1900	230	1283	3820	2578	16907	28406	10945
7	1	1	370	320	1170	5338	8200	6498	29486	29898	18148
7	2	1	410	260	920	5760	8517	6675	28616	34381	16977
7	3	1	480	320	600	5904	8430	6430	32016	27152	19090
7	1	2	550	520	650	3933	6929	5231	36931	38198	23922
7	2	2	730	420	690	3688	6640	5314	34522	41689	24831
7	3	2	540	460	400	3612	7098	4983	39143	36428	25764
7	1	3	1110	1670	490	2095	4527	3979	41623	39060	32476
7	2	3	810	1170	520	2369	5026	3481	51045	47284	21464
7	3	3	780	1250	360	2458	5173	2976	63284	45823	13841
7	1	4	830	1860	320	1934	3040	4209	37521	41404	34838
7	2	4	830	1240	500	2491	5108	2593	63992	51544	16384
7	3	4	870	1400	280	2970	3985	3104	59454	45569	25138
8	1	1	530	250	920	5417	7718	6668	13606	22265	16077
8	2	1	240	190	960	5518	7900	6814	14227	24862	18349
8	3	1	480	370	600	5400	7590	6392	12615	20921	15988
8	1	2	840	390	730	5392	6887	6343	14520	19715	14706
8	2	2	340	200	650	5160	6692	6288	14003	21216	15620
8	3	2	500	480	380	5480	6801	6501	15280	17687	14322
8	1	3	730	790	510	3759	4966	4524	11519	14547	8255
8	2	3	1010	810	340	3952	5389	4682	11287	15527	9114
8	3	3	600	650	240	5300	4664	4355	13722	12073	8826

Table B-1. Continued

TRT	REP	STAGE	ROWT	SHWT	COWT	PRO	PSH	PCO	KRO	KSH	KCO
8	1	4	1470	1190	320	2082	3902	3099	6501	11421	4946
8	2	4	1980	1210	260	2246	4182	3182	7731	11724	5860
8	3	4	720	690	200	4261	4225	3340	11973	13305	4798
9	1	1	490	320	1010	3656	2911	5767	18942	8906	17183
9	2	1	760	280	1050	3840	2814	5704	19230	9013	16854
9	3	1	540	240	650	3417	3970	5860	18776	8760	18227
9	1	2	570	440	730	3640	7021	4942	15274	25871	15790
9	2	2	830	390	900	3763	6879	4900	14830	22843	14983
9	3	2	820	590	540	3057	7160	5010	15709	24980	17511
9	1	3	1680	470	400	1111	3189	2951	12931	20849	16044
9	2	3	3700	2200	340	811	4003	2857	7311	23160	16104
9	3	3	1310	1450	280	1304	4128	3006	17000	23639	15932
9	1	4	2440	3400	340	893	2873	1578	6610	20417	12567
9	2	4	4570	2890	240	758	3259	1569	4793	21822	13762
9	3	4	1520	1640	290	1422	3443	1478	25398	20337	10488
10	1	1	630	410	800	5726	6282	5883	16290	20572	16643
10	2	1	340	290	960	9830	6395	5900	16430	21414	16844
10	3	1	300	330	590	4105	6100	5861	17182	20890	15992
10	1	2	740	520	710	6232	6491	5806	18245	21387	17307
10	2	2	410	360	770	8376	6680	5812	19212	23860	18006
10	3	2	330	320	510	3910	6117	5792	18400	22416	17314
10	1	3	1030	930	400	3192	4400	4861	9706	13915	10085
10	2	3	810	750	430	4176	5013	4176	12492	16629	12422
10	3	3	400	400	200	3976	4369	4818	10895	14244	10936
10	1	4	1000	640	360	1870	3449	5009	6109	11473	8421
10	2	4	740	930	310	5512	4862	4916	17070	15920	10253
10	3	4	460	540	180	4100	3866	4900	13110	12468	9628

Table B-1. Continued

TRT	REP	STAGE	CARO	CASH	CACO	MGRO	MGSH	MGCO	MNRO	MNSH	MNCO
1	1	1	2148	3686	3857	2528	2808	3394	11	21	40
1	2	1	2048	3786	3957	2555	2800	3400	14	21	38
1	3	1	2048	3868	3587	2428	2088	3330	10	23	41
1	1	2	3660	10194	7214	4167	2807	4443	9	19	55
1	2	2	3459	10200	6319	4200	2795	4398	13	21	49
1	3	2	3730	10102	7151	4404	2820	4400	9	20	51
1	1	3	3418	9435	13700	4132	2637	6210	5	21	77
1	2	3	3732	11583	14804	4197	2975	5920	6	23	79
1	3	3	4478	12835	11334	7936	4074	6482	22	28	74
1	1	4	1698	3137	9213	1638	2794	4702	15	37	59
1	2	4	3873	12370	13211	4757	4012	5108	9	23	61
1	3	4	7395	11481	11421	8240	3551	5332	21	34	51
2	1	1	1264	1766	3041	785	2025	3115	8	20	35
2	2	1	2014	1432	10943	1184	2488	3620	9	28	38
2	3	1	1978	3142	9212	2010	2121	3343	6	33	30
2	1	2	2096	2247	4259	979	1978	4176	9	24	44
2	2	2	4173	5312	8865	1017	1673	4560	8	27	42
2	3	2	2986	2214	8122	1364	1240	4285	7	28	48
2	1	3	1539	6559	8117	302	1158	6488	4	17	60
2	2	3	1420	7628	11010	312	1770	6329	3	18	59
2	3	3	1597	7125	12469	318	1502	6822	5	19	63
2	1	4	1780	6566	9986	235	918	6767	4	13	69
2	2	4	1347	9528	11234	232	1422	7002	5	24	60
2	3	4	2326	8103	8942	336	1155	6413	5	19	72
3	1	1	1345	1723	3078	809	2186	3244	8	22	33
3	2	1	1400	1753	3265	1011	2088	3424	6	20	27
3	3	1	1368	1708	2994	817	2401	3104	9	21	38
3	1	2	1775	2356	3539	924	2102	3578	12	26	40
3	2	2	2111	2142	3870	1010	2195	3468	10	24	43
3	3	2	1957	2436	3148	863	2011	3226	9	28	40
3	1	3	2192	5962	6988	581	1532	5219	5	14	56

Table B-1. Continued

TRT	REP	STAGE	CARO	CASH	CACO	MGRO	MGSH	MGCO	MNRO	MNSH	MNCO
3	2	3	1846	5735	5867	525	1291	5016	9	22	49
3	3	3	1635	6030	5133	348	1502	5160	8	21	50
3	1	4	3275	6226	8333	573	1250	6112	6	15	66
3	2	4	1420	6819	9234	271	1105	7010	4	21	53
3	3	4	2820	10132	8149	549	1584	6191	7	29	58
4	1	1	873	665	3085	1113	1852	3306	21	26	39
4	2	1	1042	770	3644	1437	2019	3621	22	26	45
4	3	1	904	693	3216	1382	2244	3720	20	24	49
4	1	2	788	739	3624	816	2098	3621	21	26	44
4	2	2	724	773	3469	714	2360	3982	19	28	55
4	3	2	833	814	3694	692	2418	4321	11	33	60
4	1	3	555	845	6115	347	1852	5654	9	26	64
4	2	3	606	990	6997	440	2097	6282	14	33	68
4	3	3	910	1094	6462	739	2577	5987	25	48	73
4	1	4	692	1418	6517	309	2045	6010	7	22	56
4	2	4	1860	2029	6422	929	2636	6820	16	28	63
4	3	4	1319	1271	6693	676	2981	6114	18	45	59
5	1	1	1117	1327	3236	2168	3445	3764	17	33	43
5	2	1	1158	1122	3182	2044	3160	3561	16	33	44
5	3	1	1214	1436	3049	1968	2997	3824	17	31	43
5	1	2	897	1146	3371	1724	3826	3992	17	35	47
5	2	2	814	1239	3261	1967	4988	4013	12	30	50
5	3	2	779	1159	3604	2014	5063	4140	11	29	52
5	1	3	958	1054	5691	1678	4866	7383	9	22	59
5	2	3	504	602	5932	2395	5694	7224	8	23	59
5	3	3	697	1042	6121	3765	5638	7481	8	25	55
5	1	4	764	1000	7136	2183	5386	7346	7	16	73
5	2	4	830	770	6583	2393	6199	8112	8	21	68
5	3	4	1124	905	8144	3754	5066	7120	9	18	70
6	1	1	1619	1668	3001	2203	2812	3664	14	30	40
6	2	1	1537	2315	2993	2462	2762	3592	14	32	40

Table B-1. Continued

TRT	REP	STAGE	CARO	CASH	CACO	MGRO	MGSH	MGCO	MNRO	MNSH	MNCO
6	3	1	1724	2899	3240	2817	2891	3288	12	32	42
6	1	2	3206	6014	4796	5218	3029	4462	9	29	45
6	2	2	3011	6283	4983	3386	3340	4867	8	29	44
6	3	2	3413	7341	5328	3619	3411	4760	10	30	48
6	1	3	2389	9333	9595	2885	3280	5850	3	14	59
6	2	3	3183	10636	7723	4302	3313	5217	4	16	60
6	3	3	3424	10414	8882	4528	3555	6122	8	14	59
6	1	4	2456	11298	14550	2916	3774	8704	6	15	91
6	2	4	1834	11873	14001	1559	3598	8722	9	16	87
6	3	4	4834	13476	13764	5416	4252	8961	9	24	92
7	1	1	659	847	2614	1608	3379	3719	17	33	41
7	2	1	595	696	3029	1440	3144	3936	16	29	37
7	3	1	1031	1001	1988	1812	3682	3563	18	31	41
7	1	2	850	1189	4654	2249	4918	4533	8	32	43
7	2	2	962	1045	5102	1965	5380	4260	9	28	40
7	3	2	740	912	4028	2122	4816	3894	8	33	44
7	1	3	779	617	6769	2849	4565	6514	5	18	52
7	2	3	775	653	6893	2936	5503	5670	12	16	47
7	3	3	918	717	4484	4251	6359	3989	8	20	50
7	1	4	1148	800	6131	2741	4025	6876	15	24	71
7	2	4	1131	876	6023	4575	6823	2958	8	16	65
7	3	4	1659	1048	3297	3716	6358	3486	8	15	70
8	1	1	617	868	3529	844	2115	3744	11	22	33
8	2	1	592	795	3243	830	2042	3690	12	21	37
8	3	1	610	920	3687	904	2319	3817	10	23	34
8	1	2	670	765	4435	907	2138	4381	12	22	39
8	2	2	602	944	4580	989	1960	4497	10	22	42
8	3	2	714	682	4318	1121	2287	4402	12	20	41
8	1	3	820	1055	6539	610	2263	5891	11	27	51
8	2	3	614	894	6719	523	2006	6010	8	21	50
8	3	3	846	800	6590	889	1877	5990	18	21	54

Table B-1. Continued

TRT	REP	STAGE	CARO	CASH	CACO	MGRO	MGSH	MGCO	MNRO	MNSH	MNCO
8	1	4	682	814	8733	348	1906	6975	9	25	71
8	2	4	548	1026	8868	427	1843	7030	6	18	70
8	3	4	1224	1107	8640	912	2139	6814	16	23	76
9	1	1	1762	1072	3436	1759	1082	3289	9	8	35
9	2	1	1530	1170	2984	1503	955	3166	7	10	37
9	3	1	1827	935	3760	1917	1135	3324	8	10	39
9	1	2	2087	4817	4132	2199	2663	3532	9	29	38
9	2	2	2006	5110	8224	1821	2814	3408	11	33	40
9	3	2	2141	4876	6512	2260	2930	3688	10	30	39
9	1	3	4142	10839	12686	4461	2862	6679	5	15	85
9	2	3	2292	10223	11879	2227	3391	6952	4	25	88
9	3	3	4766	10131	12590	6304	3455	6607	8	26	84
9	1	4	3257	9389	13762	2380	3028	7425	4	14	80
9	2	4	1831	10813	12857	1201	3143	7133	2	20	80
9	3	4	5483	10802	13992	6082	3402	7760	7	28	83
10	1	1	659	721	3740	969	1776	3628	11	19	38
10	2	1	593	611	3419	1003	1700	3480	10	20	36
10	3	1	630	742	3815	915	1695	3816	10	18	36
10	1	2	809	761	3582	1027	2027	3713	14	22	33
10	2	2	815	699	3769	1116	1860	3921	13	21	34
10	3	2	908	781	4100	998	2112	3800	11	20	36
10	1	3	617	792	5382	527	1886	4909	10	21	50
10	2	3	580	866	5490	504	1951	5104	7	21	49
10	3	3	883	1168	5019	874	1894	4799	12	24	47
10	1	4	1137	1126	6061	802	2205	5587	16	24	53
10	2	4	1367	1423	6442	896	2095	5919	11	22	51
10	3	4	1759	918	5228	1106	1661	5612	16	17	50

Table B-1. Continued

TRT	REP	STAGE	BRO	BSH	BCO	NARO	NASH	NACO	FERO	FESH	FECO
1	1	1	16	33	36	129	91	24	125	83	79
1	2	1	15	32	30	137	89	22	130	80	75
1	3	1	15	30	34	122	88	23	120	80	76
1	1	2	11	29	41	370	53	48	105	69	71
1	2	2	14	30	44	352	58	49	100	73	74
1	3	2	13	32	40	367	51	53	98	71	69
1	1	3	10	22	46	756	61	35	106	68	69
1	2	3	10	28	44	765	59	40	92	63	71
1	3	3	13	27	42	103	48	39	125	65	68
1	1	4	13	36	38	122	56	35	63	97	66
1	2	4	8	32	40	264	50	32	87	57	68
1	3	4	12	26	40	165	38	43	114	57	64
2	1	1	13	33	34	231	88	38	60	78	71
2	2	1	14	33	36	260	80	45	68	70	72
2	3	1	13	30	34	253	79	51	72	69	66
2	1	2	16	29	40	314	74	56	77	76	79
2	2	2	12	30	41	319	69	50	92	75	75
2	3	2	10	28	37	321	76	49	88	73	82
2	1	3	5	15	58	454	29	28	145	82	90
2	2	3	6	23	49	169	25	24	106	95	88
2	3	3	6	14	51	116	24	55	122	86	89
2	1	4	4	12	64	262	23	36	157	83	88
2	2	4	4	17	62	111	25	30	169	91	90
2	3	4	6	13	64	382	26	32	130	106	91
3	1	1	14	32	32	286	277	47	83	93	69
3	2	1	18	28	33	288	261	46	73	86	70
3	3	1	10	24	30	280	270	51	72	97	62
3	1	2	14	30	34	294	159	58	87	92	82
3	2	2	14	31	32	316	190	43	91	88	80
3	3	2	12	31	35	354	138	50	100	84	80
3	1	3	10	13	52	652	42	33	187	76	90

Table B-1. Continued

TRT	REP	STAGE	BRO	BSH	BCO	NARO	NASH	NACO	FERO	FESH	FECO
3	2	3	10	20	42	271	24	30	184	87	83
3	3	3	7	15	48	242	25	26	99	97	79
3	1	4	9	12	58	738	22	88	167	72	96
3	2	4	5	19	56	138	30	89	174	87	92
3	3	4	8	17	61	312	29	97	203	95	101
4	1	1	17	29	33	267	57	26	107	83	73
4	2	1	20	22	33	309	72	29	98	95	88
4	3	1	17	29	37	288	89	37	124	102	89
4	1	2	13	30	35	483	132	102	130	93	84
4	2	2	11	28	39	499	128	89	188	104	92
4	3	2	14	33	42	444	136	95	196	127	104
4	1	3	8	18	52	573	106	33	240	165	125
4	2	3	9	38	61	457	61	41	262	120	129
4	3	3	15	28	68	346	45	36	310	147	134
4	1	4	7	20	52	733	75	80	284	145	136
4	2	4	17	40	55	605	57	79	401	139	130
4	3	4	12	19	47	284	39	81	263	201	143
5	1	1	21	39	37	216	115	35	101	90	78
5	2	1	20	39	36	211	120	37	104	88	76
5	3	1	21	38	37	204	114	33	96	91	76
5	1	2	21	37	37	225	104	35	79	95	77
5	2	2	20	36	34	260	110	36	98	94	76
5	3	2	19	36	43	243	114	39	114	92	77
5	1	3	18	26	51	270	127	47	230	77	78
5	2	3	12	35	50	180	114	47	119	60	72
5	3	3	14	27	48	237	96	48	101	62	69
5	1	4	12	24	57	487	186	71	333	70	80
5	2	4	14	31	70	288	117	68	207	78	90
5	3	4	17	20	64	221	155	66	257	44	83
6	1	1	19	35	34	212	130	32	94	83	71
6	2	1	17	34	36	220	126	30	102	80	70

Table B-1. Continued

TRT	REP	STAGE	BRO	BSH	BCO	NARO	NASH	NACO	FERO	FESH	FECO
6	3	1	19	35	38	284	124	32	100	80	72
6	1	2	16	32	41	303	92	47	101	77	79
6	2	2	18	33	42	397	104	45	112	81	81
6	3	2	14	32	44	404	97	45	110	79	84
6	1	3	9	27	50	460	45	39	186	91	86
6	2	3	10	30	55	370	30	37	150	97	88
6	3	3	10	28	51	192	39	39	131	75	88
6	1	4	7	29	77	296	31	95	170	78	107
6	2	4	5	33	75	258	38	98	108	89	100
6	3	4	11	32	79	114	34	93	148	75	112
7	1	1	20	39	35	290	137	36	144	107	84
7	2	1	20	42	32	286	141	34	158	111	80
7	3	1	18	40	37	289	140	38	142	104	83
7	1	2	14	31	41	298	120	30	100	96	78
7	2	2	16	27	39	297	124	27	99	93	75
7	3	2	14	30	44	290	120	32	93	99	77
7	1	3	15	27	55	201	180	91	126	55	86
7	2	3	14	33	58	208	198	86	146	61	81
7	3	3	18	29	55	141	168	112	174	56	76
7	1	4	17	22	47	282	94	131	254	87	69
7	2	4	17	35	49	230	156	127	138	60	73
7	3	4	19	27	47	240	100	134	168	73	68
8	1	1	12	34	33	206	307	67	100	82	68
8	2	1	12	33	36	216	318	43	96	88	63
8	3	1	15	34	30	225	326	81	104	80	71
8	1	2	13	29	42	423	168	76	141	90	80
8	2	2	10	29	40	409	193	92	140	94	82
8	3	2	14	28	45	440	214	127	144	101	75
8	1	3	15	24	49	392	95	45	265	137	114
8	2	3	8	33	53	273	58	67	273	130	110
8	3	3	14	21	51	410	59	96	177	93	120

Table B-1. Continued

TRT	REP	STAGE	BRO	BSH	BCO	NARO	NASH	NACO	FERO	FESH	FECO
8	1	4	8	22	65	332	50	257	281	144	140
8	2	4	8	27	68	213	231	168	232	97	140
8	3	4	15	24	66	436	71	204	239	124	137
9	1	1	12	9	34	114	3	3	69	27	69
9	2	1	12	10	34	118	3	3	70	41	71
9	3	1	11	11	36	109	4	5	76	38	68
9	1	2	12	31	35	93	3	3	64	79	69
9	2	2	10	32	34	100	2	3	71	77	69
9	3	2	12	30	37	98	3	5	80	81	71
9	1	3	7	10	59	765	3	2	87	84	91
9	2	3	5	15	63	426	47	3	78	109	100
9	3	3	9	15	60	186	44	4	89	110	97
9	1	4	7	9	62	330	43	74	106	62	85
9	2	4	5	14	66	314	41	73	88	73	92
9	3	4	9	9	61	135	35	76	106	70	88
10	1	1	15	31	35	302	61	26	101	81	79
10	2	1	16	30	34	310	63	26	100	76	80
10	3	1	17	31	34	306	66	24	112	80	81
10	1	2	16	33	35	526	104	48	116	86	77
10	2	2	14	33	35	602	100	44	120	88	74
10	3	2	15	34	33	580	108	46	122	93	76
10	1	3	15	24	48	370	96	39	213	131	96
10	2	3	9	38	46	770	87	41	176	109	99
10	3	3	10	27	44	665	132	40	144	119	100
10	1	4	11	26	51	142	65	66	253	120	110
10	2	4	12	34	50	774	33	66	240	98	111
10	3	4	16	20	47	459	170	70	246	116	110

Table B-1. Continued

TRT	REP	STAGE	CURO	CUSH	CUCO	ZNRO	ZNSH	ZNCO	ALRO	ALSH	ALCO
1	1	1	17	18	13	41	63	36	123	34	12
1	2	1	15	17	11	44	62	36	131	33	11
1	3	1	15	15	12	42	60	30	122	34	11
1	1	2	14	12	11	18	30	31	196	32	27
1	2	2	15	14	10	22	31	32	188	35	24
1	3	2	12	11	13	24	34	34	214	33	28
1	1	3	8	9	9	11	30	23	206	30	48
1	2	3	10	10	11	15	32	26	142	49	39
1	3	3	15	9	12	23	31	24	128	39	41
1	1	4	21	20	10	55	67	30	74	42	36
1	2	4	4	5	9	7	22	36	98	34	38
1	3	4	7	6	10	25	31	33	94	29	30
2	1	1	20	19	12	45	59	37	77	24	10
2	2	1	16	21	10	41	58	33	73	22	14
2	3	1	18	18	11	38	59	38	70	24	12
2	1	2	24	18	12	53	98	34	108	26	14
2	2	2	12	18	9	42	97	32	110	24	16
2	3	2	16	14	10	36	89	33	119	26	14
2	1	3	4	14	9	12	36	28	204	22	18
2	2	3	6	12	8	19	45	29	173	21	18
2	3	3	10	10	6	19	41	28	179	21	19
2	1	4	7	9	7	8	29	21	191	31	40
2	2	4	3	11	8	6	42	20	162	29	39
2	3	4	3	8	6	20	45	19	170	45	42
3	1	1	18	21	13	45	54	40	105	40	11
3	2	1	16	21	14	48	54	43	108	44	10
3	3	1	16	20	14	40	50	39	100	41	10
3	1	2	24	21	15	51	61	39	119	37	14
3	2	2	22	20	14	50	63	42	108	40	15
3	3	2	20	19	12	46	56	31	127	36	14
3	1	3	15	11	12	28	33	28	354	42	29

Table B-1. Continued

TRT	REP	STAGE	CURO	CUSH	CUCO	ZNRO	ZNSH	ZNCO	ALRO	ALSH	ALCO
3	2	3	13	13	10	37	45	26	271	45	31
3	3	3	7	12	11	25	67	31	252	48	27
3	1	4	4	9	7	15	33	26	325	36	48
3	2	4	2	10	7	10	38	22	182	31	39
3	3	4	5	7	8	12	36	30	283	33	53
4	1	1	25	23	12	67	54	37	123	42	14
4	2	1	24	22	12	63	50	46	123	44	16
4	3	1	26	20	14	69	52	39	128	48	14
4	1	2	21	19	14	54	59	35	121	50	17
4	2	2	22	20	16	43	60	38	138	60	28
4	3	2	18	17	12	31	52	32	142	62	32
4	1	3	11	16	13	33	44	26	183	72	109
4	2	3	18	19	16	46	65	40	193	47	120
4	3	3	35	11	18	53	52	43	241	54	124
4	1	4	13	15	8	24	40	27	314	38	32
4	2	4	23	18	9	79	77	24	329	45	50
4	3	4	15	8	6	45	56	32	232	36	88
5	1	1	25	20	16	75	69	45	149	69	18
5	2	1	24	21	14	81	72	40	150	65	18
5	3	1	24	22	13	79	66	42	144	66	17
5	1	2	24	24	12	94	93	40	138	53	19
5	2	2	23	20	12	93	80	39	167	51	27
5	3	2	20	18	11	90	83	39	169	50	22
5	1	3	22	17	12	36	37	37	415	46	53
5	2	3	15	13	10	23	48	39	192	59	47
5	3	3	14	8	11	26	48	44	157	51	49
5	1	4	10	10	9	13	26	30	123	55	52
5	2	4	8	9	10	17	37	29	410	57	47
5	3	4	8	4	10	22	23	34	331	32	40
6	1	1	32	20	12	96	67	43	124	44	19
6	2	1	34	22	11	81	60	41	122	41	16

Table B-1. Continued

TRT	REP	STAGE	CURO	CUSH	CUCO	ZNRO	ZNSH	ZNCO	ALRO	ALSH	ALCO
6	3	1	30	20	10	73	59	43	130	43	20
6	1	2	17	17	13	45	68	39	143	47	28
6	2	2	17	18	12	33	52	40	188	41	25
6	3	2	14	14	10	29	43	38	167	43	30
6	1	3	11	12	8	15	37	28	210	40	58
6	2	3	10	14	6	19	41	33	194	50	47
6	3	3	8	8	9	16	35	26	149	30	51
6	1	4	7	11	7	8	31	24	198	46	70
6	2	4	3	9	7	5	36	22	131	36	69
6	3	4	5	6	6	16	37	26	179	40	75
7	1	1	30	25	14	88	83	47	195	78	21
7	2	1	33	26	13	89	87	49	201	87	24
7	3	1	28	22	12	76	80	44	190	71	31
7	1	2	21	17	16	41	67	41	183	64	30
7	2	2	22	15	16	43	62	41	195	68	40
7	3	2	20	14	14	38	55	39	178	47	41
7	1	3	22	10	11	32	40	48	278	46	77
7	2	3	27	12	10	39	44	44	286	57	72
7	3	3	15	9	16	32	40	48	263	34	87
7	1	4	10	6	10	23	29	31	300	105	63
7	2	4	11	10	10	22	47	32	319	114	69
7	3	4	12	5	9	33	31	30	266	66	71
8	1	1	18	21	13	57	62	39	125	50	16
8	2	1	16	20	11	55	66	42	130	55	14
8	3	1	20	22	10	60	62	37	127	51	18
8	1	2	24	20	15	66	57	38	155	59	36
8	2	2	22	24	14	62	46	40	154	61	37
8	3	2	19	21	12	64	42	41	169	56	35
8	1	3	25	20	12	57	62	32	315	81	36
8	2	3	23	19	11	48	55	30	184	31	38
8	3	3	21	13	10	68	47	34	138	46	41

Table B-1. Continued

TRT	REP	STAGE	CURO	CUSH	CUCO	ZNRO	ZNSH	ZNCO	ALRO	ALSH	ALCO
8	1	4	13	14	7	31	54	38	280	43	66
8	2	4	8	11	9	23	41	36	404	26	69
8	3	4	15	11	6	55	54	40	229	42	66
9	1	1	29	3	13	65	26	41	120	5	5
9	2	1	30	8	11	64	26	43	124	5	5
9	3	1	29	10	12	66	28	40	118	6	6
9	1	2	18	18	11	38	59	34	101	29	10
9	2	2	18	18	10	33	63	36	119	30	10
9	3	2	17	19	11	47	61	32	110	31	11
9	1	3	13	10	13	21	27	32	191	20	53
9	2	3	5	10	13	13	38	33	153	48	51
9	3	3	8	10	12	26	40	28	178	38	63
9	1	4	7	8	6	10	29	25	269	35	86
9	2	4	3	7	8	7	32	21	184	36	84
9	3	4	13	9	6	44	58	28	137	30	91
10	1	1	21	19	13	56	51	34	90	34	19
10	2	1	20	20	12	63	52	34	86	32	21
10	3	1	21	20	12	58	50	33	88	35	18
10	1	2	31	19	12	79	59	34	118	30	14
10	2	2	30	20	10	80	58	35	109	38	16
10	3	2	32	19	11	69	49	36	114	31	15
10	1	3	22	18	13	49	63	30	204	60	19
10	2	3	35	19	14	52	58	30	135	51	23
10	3	3	26	18	12	41	39	31	152	38	19
10	1	4	30	26	11	40	49	31	175	64	32
10	2	4	15	15	10	52	53	31	170	26	33
10	3	4	11	8	10	47	31	31	160	59	30

Table B-2. Nutrient content of seedlings and each portion thereof for plants treated with different nutrient solutions

TRT	REP	STAGE	TP	PRO	PSH	PCO	TK	KRO	KSH	KCO
1	1	1	11.4398	2.16580	4.0680	5.20608	57.599	18.1805	18.0326	21.3859
1	2	1	9.3885	1.00160	2.4326	5.95422	45.206	9.2096	10.7855	25.2111
1	3	1	6.9532	1.22148	2.1114	3.62032	34.664	10.8381	9.3628	14.4636
1	1	2	6.5038	1.22196	1.7071	3.57483	46.442	11.9782	13.4348	21.0288
1	2	2	6.6009	1.61980	2.0900	2.89110	48.795	15.7904	16.4472	16.5572
1	3	2	4.7862	0.98800	1.8865	1.91176	35.939	9.8290	15.0506	11.0589
1	1	3	11.0923	2.09364	8.1315	0.86724	100.190	28.0977	61.8286	10.2636
1	2	3	11.4060	2.45616	7.7190	1.23082	100.305	34.7800	53.5066	12.0187
1	3	3	7.7942	1.26647	5.5889	0.93885	76.942	26.9118	41.8176	8.2127
1	1	4	30.9379	7.72200	22.0566	1.15929	153.736	61.2090	85.5036	7.0234
1	2	4	10.9342	2.56424	7.4442	0.92580	126.457	42.5510	76.0631	7.8426
1	3	4	8.2132	1.58873	5.9016	0.72289	102.519	34.7418	62.9135	4.8640
2	1	1	10.0850	2.27150	2.0208	5.79272	30.470	7.1820	6.1347	17.1536
2	2	1	9.0506	2.31080	1.8446	4.89512	29.623	8.3539	5.6042	15.6649
2	3	1	5.9950	1.22760	1.7992	2.96820	17.425	4.6131	5.5245	7.2874
2	1	2	9.8505	3.13472	2.6733	4.04250	28.342	9.9845	8.2526	10.1052
2	2	2	9.3033	2.97656	2.3864	3.94030	26.016	8.3027	7.0175	10.6960
2	3	2	6.7808	2.37915	2.1212	2.28040	16.129	5.3532	6.0179	4.7584
2	1	3	9.3061	2.98782	4.9464	1.37186	26.431	9.2248	14.8118	2.3940
2	2	3	9.6729	3.63858	4.9290	1.10530	28.316	12.4475	13.3090	2.5599
2	3	3	7.0720	3.08470	3.1130	0.87425	20.433	11.5845	7.7759	1.0722
2	1	4	9.2623	3.41130	5.1763	0.67470	28.425	13.3698	14.0083	1.0467
2	2	4	10.0012	4.41367	4.9594	0.62816	28.048	13.3398	13.6657	1.0429
2	3	4	7.5819	3.67939	3.3193	0.58322	22.750	13.1490	8.8134	0.7874
3	1	1	10.0260	1.41702	2.2922	6.31680	29.513	4.7091	7.4253	17.3790
3	2	1	9.6401	1.47140	1.4463	6.72240	29.409	5.6493	4.8472	18.9120
3	3	1	6.7869	2.03780	2.3136	2.43552	20.232	6.7749	7.0841	6.3730
3	1	2	9.1701	2.32064	1.7615	5.08800	26.797	7.3211	5.4772	13.9987
3	2	2	8.5868	3.32960	2.2152	3.04200	29.031	12.2888	7.8447	8.8972
3	3	2	6.4179	2.19890	2.2674	1.95160	20.639	6.8673	7.6420	6.1299
3	1	3	7.8034	2.10120	3.9368	1.76543	25.391	9.7092	11.6162	4.0651

Table B-2. Continued

TRT	REP	STAGE	TP	PRO	PSH	PCO	TK	KRO	KSH	KCO
3	2	3	6.2791	2.52356	2.57380	1.18170	17.693	8.2542	6.592	2.8466
3	3	3	6.2276	2.67518	2.86240	0.69000	19.709	9.5079	8.463	1.7375
3	1	4	9.3347	3.29875	4.92264	1.11333	32.056	13.3412	16.552	2.1638
3	2	4	7.3971	1.67832	4.68174	1.03705	18.746	4.7207	12.171	1.8543
3	3	4	6.6173	2.84160	3.17317	0.60258	22.655	12.1190	8.700	1.8366
4	1	1	9.2309	2.09814	2.22057	4.91218	27.079	6.3931	7.438	13.2478
4	2	1	8.3590	1.92570	1.86840	4.56488	22.940	5.6991	6.165	11.0759
4	3	1	8.0668	2.56620	1.92078	3.57984	16.412	8.3577	6.842	1.2118
4	1	2	10.1001	3.13800	2.10210	4.86000	28.556	9.5742	6.584	12.3984
4	2	2	8.8697	3.14442	2.41332	3.31200	21.667	6.9514	7.857	6.8592
4	3	2	6.5434	2.49664	2.01201	2.03480	17.621	6.1758	7.050	4.3952
4	1	3	8.2718	2.48336	4.31210	1.47630	25.038	8.2715	14.006	2.7602
4	2	3	10.1278	4.23900	4.03600	1.85280	29.879	13.5590	13.024	3.2956
4	3	3	6.5611	3.10500	2.54526	0.91080	19.353	10.0319	7.572	1.7494
4	1	4	8.6727	2.37273	4.79806	1.50192	31.006	9.7800	18.162	3.0636
4	2	4	11.1810	5.81724	3.61692	1.74681	32.460	18.6506	10.503	3.3072
4	3	4	7.6264	4.31317	2.37323	0.94001	19.510	11.5356	6.066	1.9083
5	1	1	10.3801	1.89000	1.92432	6.56574	38.517	11.7580	8.208	18.5507
5	2	1	11.6514	1.91919	2.36348	7.36873	41.568	11.4082	9.520	20.6394
5	3	1	10.2502	2.52014	3.07692	4.65312	38.666	13.9881	12.299	12.3787
5	1	2	11.2198	2.54656	3.51760	5.15565	40.202	12.8487	12.880	14.4731
5	2	2	9.2969	2.77928	2.94520	3.57244	43.558	17.0447	11.856	14.6568
5	3	2	8.3558	3.32304	2.91240	2.12040	43.567	21.9282	13.258	8.3812
5	1	3	12.7758	2.34480	8.77220	1.65880	136.650	43.5456	80.139	12.9656
5	2	3	9.9433	1.97376	5.77616	2.19336	99.981	34.9555	46.762	18.2640
5	3	3	9.3847	2.18203	5.95496	1.24768	117.405	49.8454	57.412	10.1472
5	1	4	10.0462	2.08662	6.74488	1.21473	159.086	47.7233	101.756	9.6063
5	2	4	11.3762	2.27557	7.14744	1.95320	132.990	51.9901	65.586	15.4140
5	3	4	8.0527	2.73628	4.53407	0.78240	128.566	63.8684	54.156	10.5422
6	1	1	11.0531	2.24952	2.63935	6.16427	32.151	8.4706	8.094	15.5867
6	2	1	8.7077	2.27250	1.75825	4.67695	27.488	10.0435	5.366	12.0791

Table B-2. Continued

TRT	REP	STAGE	TP	PRO	PSH	PCO	TK	KRO	KSH	KCO
6	3	1	7.9643	2.22210	1.94376	3.79848	27.495	11.1573	5.7641	10.5740
6	1	2	11.4756	3.28512	4.79944	3.39105	48.403	17.4422	20.2463	10.7146
6	2	2	7.1806	1.30626	3.00006	2.87424	32.734	8.4848	11.0943	13.1551
6	3	2	7.0064	2.20800	3.01043	1.78801	29.430	12.9216	9.8866	6.6223
6	1	3	11.4657	1.94970	8.82337	0.69264	67.008	15.0529	48.2320	3.7231
6	2	3	13.3915	2.58672	9.97454	0.83027	78.460	26.4547	48.7000	3.3051
6	3	3	9.0714	2.38980	5.97600	0.70564	64.125	25.4352	34.7112	3.9783
6	1	4	10.9945	2.34880	8.17530	0.47040	97.498	28.4928	65.9212	3.0835
6	2	4	12.7642	2.80899	9.49468	0.46050	99.196	26.9058	69.3502	2.9405
6	3	4	10.7377	2.88675	7.25800	0.59294	94.529	38.0407	53.9714	2.5173
7	1	1	12.2017	1.97506	2.62400	7.60266	41.710	10.9098	9.5674	21.2332
7	2	1	10.7170	2.36160	2.21442	6.14100	36.290	11.7326	8.9391	15.6188
7	3	1	9.3895	2.83392	2.69760	3.85800	35.510	15.3677	8.6886	11.4540
7	1	2	8.9464	1.94315	3.60308	3.40015	55.724	20.3120	19.8630	15.5493
7	2	2	9.1477	2.69224	2.78880	3.66666	59.844	25.2011	17.5094	17.1334
7	3	2	7.2088	1.95048	3.26508	1.99320	48.200	21.1372	16.7569	10.3056
7	1	3	11.8352	2.32545	7.56009	1.94971	127.345	46.2015	65.2302	15.9132
7	2	3	9.6094	1.91889	5.88042	1.81012	107.830	41.3464	55.3223	11.1613
7	3	3	9.4548	1.91724	6.46625	1.07136	111.623	49.3615	57.2787	4.9828
7	1	4	8.6065	1.60522	5.65440	1.34688	119.302	31.1424	77.0114	11.1482
7	2	4	9.6979	2.06753	6.33392	1.29650	125.220	53.1134	63.9146	8.1920
7	3	4	9.0320	2.58390	5.57900	0.86912	122.560	51.7250	63.7966	7.0386
8	1	1	10.9351	2.87101	1.92950	6.13456	27.568	7.2112	5.5662	14.7908
8	2	1	9.3668	1.32432	1.50100	6.54144	25.753	3.4145	4.7238	17.6150
8	3	1	9.2355	2.59200	2.80830	3.83520	23.389	6.0552	7.7408	9.5928
8	1	2	11.8456	4.52928	2.68593	4.63039	30.621	12.1968	7.6888	10.7354
8	2	2	7.1800	1.75440	1.33840	4.08720	19.157	4.7610	4.2432	10.1530
8	3	2	8.4749	2.74000	3.26448	2.47038	21.572	7.6400	8.4898	5.4424
8	1	3	8.9744	2.74407	3.92314	2.30724	24.111	8.4089	11.4921	4.2100
8	2	3	9.9485	3.99152	4.36509	1.59188	27.075	11.3999	12.5769	3.0988
8	3	3	7.2568	3.18000	3.03160	1.04520	18.199	8.2332	7.8474	2.1182

Table B-2. Continued

TRT	REP	STAGE	TP	PRO	PSH	PCO	TK	KRO	KSH	KCO
8	1	4	8.6956	3.06054	4.64338	0.99168	24.7302	9.5565	13.5910	1.5827
8	2	4	10.3346	4.44708	5.06022	0.82732	31.0170	15.3074	14.1860	1.5236
8	3	4	6.6512	3.06792	2.91525	0.66800	18.7606	8.6206	9.1804	0.9596
9	1	1	8.5476	1.79144	0.93152	5.82467	29.4863	9.2816	2.8499	17.3548
9	2	1	9.6955	2.91840	0.78792	5.98920	34.8351	14.6148	2.5236	17.6967
9	3	1	6.6070	1.84518	0.95280	3.80900	24.0890	10.1390	2.1024	11.8475
9	1	2	8.7717	2.07480	3.06924	3.60766	31.6161	8.7062	11.3832	11.5267
9	2	2	10.2161	3.12329	2.68281	4.41000	34.7024	12.3089	8.9088	13.4847
9	3	2	9.4365	2.50674	4.22440	2.70540	37.0755	12.8814	14.7382	9.4559
9	1	3	4.5457	1.86648	1.49883	1.18040	37.9407	21.7241	9.7990	6.4176
9	2	3	12.7923	3.00070	8.80660	0.98498	83.4781	27.0507	50.9520	5.4754
9	3	3	8.5355	1.70824	5.98560	0.84168	61.0075	22.2700	34.2765	4.4610
9	1	4	12.4836	2.17892	9.76820	0.53652	89.8190	16.1284	69.4178	4.2728
9	2	4	13.2591	3.46406	9.41851	0.37656	88.2725	21.9040	63.0656	3.3029
9	3	4	8.2366	2.16144	5.64652	0.42862	74.9992	38.6050	33.3527	3.0415
10	1	1	10.8894	3.60738	2.57562	4.70640	32.0116	10.2627	8.4345	13.3144
10	2	1	10.8607	3.34220	1.85455	5.66400	27.9665	5.5862	6.2101	16.1702
10	3	1	6.7025	1.23150	2.01300	3.45799	21.4836	5.1546	6.8937	9.4353
10	1	2	12.1093	4.61168	3.37532	4.12226	36.9105	13.5013	11.1212	12.2880
10	2	2	10.3142	3.43416	2.40480	4.47524	30.3311	7.8769	8.5896	13.8646
10	3	2	6.2017	1.29030	1.95744	2.95392	22.0753	6.0720	7.1731	8.8301
10	1	3	9.3242	3.28776	4.09200	1.94440	26.9721	9.9972	12.9409	4.0340
10	2	3	8.9380	3.38256	3.75975	1.79568	27.9317	10.1185	12.4717	5.3415
10	3	3	4.3016	1.59040	1.74760	0.96360	12.2428	4.3580	5.6976	2.1872
10	1	4	5.8806	1.87000	2.20736	1.80324	16.4833	6.1090	7.3427	3.0316
10	2	4	10.1245	4.07888	4.52166	1.52396	30.6158	12.6318	14.8056	3.1784
10	3	4	4.8556	1.88600	2.08764	0.88200	14.4964	6.0306	6.7327	1.7330

Table B-2. Continued

TRT	REP	STAGE	TCA	CARO	CASH	CACO	TMG	MGRO	MGSH	MGCO
1	1	1	7.0156	1.3962	1.9167	3.70272	6.3616	1.6432	1.46016	3.25824
1	2	1	6.3438	0.6554	1.1774	4.51098	5.5644	0.8176	0.87080	3.87600
1	3	1	4.2822	0.7987	1.0444	2.43916	3.7751	0.9469	0.56376	2.26440
1	1	2	13.4542	2.4888	4.6892	6.27618	7.9902	2.8336	1.29122	3.86541
1	2	2	13.0486	3.0785	5.6100	4.36011	8.3099	3.7380	1.53725	3.03462
1	3	2	10.3811	1.9396	5.1520	3.28946	5.7523	2.2901	1.43820	2.02400
1	1	3	34.7784	7.4854	22.3609	4.93200	17.5344	9.0491	6.24969	2.23560
1	2	3	35.2273	7.6133	21.5444	6.06964	16.5226	8.5619	5.53350	2.42720
1	3	3	24.6678	3.9854	16.9422	3.74022	14.5798	7.0630	5.37768	2.13906
1	1	4	18.1966	4.5846	10.5717	3.04029	15.3900	4.4226	9.41578	1.55166
1	2	4	41.5008	9.3339	28.2036	3.96330	22.1441	11.4644	9.14736	1.53240
1	3	4	36.9673	10.5748	23.7657	2.62683	20.3601	11.7832	7.35057	1.22636
2	1	1	4.2940	0.6320	0.5298	3.13223	4.2084	0.3925	0.60750	3.20845
2	2	1	10.8794	1.0674	0.4010	9.41098	4.4374	0.6275	0.69664	3.11320
2	3	1	6.1678	0.6527	0.8169	4.69812	2.9197	0.6633	0.55146	1.70493
2	1	2	5.2246	1.2995	0.9437	2.98130	4.3609	0.6070	0.83076	2.92320
2	2	2	10.6444	2.4203	2.0186	6.20550	4.4176	0.5899	0.63574	3.19200
2	3	2	5.3231	1.3437	0.7306	3.24880	2.7370	0.6138	0.40920	1.71400
2	1	3	17.3438	4.5708	9.4450	3.32797	5.2245	0.8969	1.66752	2.66008
2	2	3	17.1624	4.2316	9.0773	3.85350	5.2512	0.9298	2.10630	2.21515
2	3	3	12.5837	3.4815	5.9850	3.11725	3.6604	0.6932	1.25168	1.70550
2	1	4	22.9183	7.3158	12.6067	2.99580	4.7585	0.9658	1.76256	2.03010
2	2	4	22.0222	6.0480	13.0534	2.92084	4.8103	1.0417	1.94814	1.82052
2	3	4	19.4604	7.9317	9.5615	1.96724	3.9195	1.1458	1.36290	1.41086
3	1	1	4.4598	0.4438	0.5686	3.44736	4.6216	0.2670	0.72138	3.63328
3	2	1	4.7761	0.4900	0.3681	3.91800	4.9011	0.3538	0.43848	4.10880
3	3	1	2.4803	0.6293	0.5636	1.28742	2.5029	0.3758	0.79233	1.33472
3	1	2	4.8797	0.8697	0.6126	3.39744	4.4342	0.4528	0.54652	3.43488
3	2	2	4.9968	1.6888	0.7925	2.51550	3.8743	0.8080	0.81215	2.25420
3	3	2	3.2683	1.0763	0.9013	1.29068	2.5414	0.4746	0.74407	1.32266
3	1	3	14.2635	2.6304	7.9295	3.70364	5.5008	0.6972	2.03756	2.76607

Table B-2. Continued

TRT	REP	STAGE	TCA	CARO	CASH	CACO	TMG	MGRO	MGSH	MGCO
3	2	3	7.8862	1.69832	3.8998	2.28813	3.3171	0.48300	0.8779	1.95624
3	3	3	9.0666	2.95935	4.8240	1.28325	3.1215	0.62988	1.2016	1.29000
3	1	4	20.4402	6.64825	10.7087	3.08321	5.5746	1.16319	2.1500	2.26144
3	2	4	15.2153	2.30040	9.6830	3.23190	4.4616	0.43902	1.5691	2.45350
3	3	4	17.2733	6.26040	9.2201	1.79278	4.0222	1.21878	1.4414	1.36202
4	1	1	3.3149	0.28809	0.2194	2.80735	3.9869	0.36729	0.6112	3.00846
4	2	1	3.6543	0.31260	0.2079	3.13384	4.0903	0.43110	0.5451	3.11406
4	3	1	2.6622	0.35256	0.1871	2.12256	3.6001	0.53898	0.6059	2.45520
4	1	2	3.9783	0.47280	0.2439	3.26160	4.4408	0.48960	0.6923	3.25890
4	2	2	2.7738	0.39096	0.3015	2.08140	3.6952	0.38556	0.9204	2.38920
4	3	2	2.1377	0.39151	0.2686	1.47760	2.8516	0.32524	0.7979	1.72840
4	1	3	3.9215	0.75480	0.9041	2.26255	4.5455	0.47192	1.9816	2.09198
4	2	3	4.1968	0.60600	0.7920	2.79880	4.6304	0.44000	1.6776	2.51280
4	3	3	2.6950	0.62790	0.6455	1.42164	3.3475	0.50991	1.5204	1.31714
4	1	4	5.1089	0.96188	1.8009	2.34612	5.1903	0.42951	2.5971	2.16360
4	2	4	5.7257	1.84140	1.3797	2.50458	5.3720	0.91971	1.7925	2.65980
4	3	4	4.3006	1.83341	0.9278	1.53939	4.5220	0.93964	2.1761	1.40622
5	1	1	4.0213	0.40212	0.3185	3.30072	5.4466	0.78048	0.8268	3.83928
5	2	1	4.3383	0.42846	0.3142	3.59566	5.6650	0.75628	0.8848	4.02393
5	3	1	3.3582	0.57058	0.5313	2.25626	4.8636	0.92496	1.1089	2.82976
5	1	2	3.6015	0.41262	0.4584	2.73051	5.5570	0.79304	1.5304	3.23352
5	2	2	2.9361	0.45584	0.4584	2.02182	5.4351	1.10152	1.8456	2.48806
5	3	2	2.4427	0.53751	0.4636	1.44160	5.0709	1.38966	2.0252	1.65600
5	1	3	5.8502	1.14960	2.4242	2.27640	16.1586	2.01360	11.1918	2.95320
5	2	3	4.1946	0.48384	0.6261	3.08464	11.9774	2.29920	5.9218	3.75648
5	3	3	3.8978	0.78761	1.3963	1.71388	13.9040	4.25445	7.5549	2.09468
5	1	4	5.9831	1.26824	2.3600	2.35488	18.7589	3.62378	12.7110	2.42418
5	2	4	5.0177	1.13710	1.2474	2.63320	16.5656	3.27841	10.0424	3.24480
5	3	4	4.8092	1.50616	1.3484	1.95456	14.2875	5.03036	7.5483	1.70880
6	1	1	4.4748	0.67998	0.5838	3.21107	5.8299	0.92526	0.9842	3.92048
6	2	1	3.9342	0.69165	0.5787	2.66377	4.9953	1.10790	0.6905	3.19688

Table B-2. Continued

TRT	REP	STAGE	TCA	CARO	CASH	CACO	TMG	MGRO	MGSH	MGCO
6	3	1	3.7907	0.7758	0.8117	2.20320	4.3130	1.2676	0.80948	2.23584
6	1	2	10.2847	3.0778	4.0895	3.11740	9.9693	5.0093	2.05972	2.90030
6	2	2	8.0031	1.7765	2.6389	3.58776	6.9048	1.9977	1.40280	3.50424
6	3	2	8.0715	2.7304	3.1566	2.18448	6.3135	2.8952	1.46673	1.95160
6	1	3	29.6287	4.8019	21.3726	3.45420	15.4160	5.7988	7.51120	2.10600
6	2	3	31.4940	6.4933	22.7610	2.23967	17.3788	8.7761	7.08982	1.51293
6	3	3	24.4959	7.1904	14.9962	2.30932	16.2197	9.5088	5.11920	1.59172
6	1	4	38.2404	7.8592	26.8892	3.49200	20.4023	9.3312	8.98212	2.08896
6	2	4	42.5651	9.7385	29.3263	3.50025	19.3458	8.2783	8.88706	2.18050
6	3	4	39.6466	10.8765	25.6044	3.16572	22.3258	12.1860	8.07880	2.06103
7	1	1	3.5732	0.2438	0.2710	3.05838	6.0275	0.5950	1.08128	4.35123
7	2	1	3.2116	0.2439	0.1810	2.78668	5.0290	0.5904	0.81744	3.62112
7	3	1	2.0080	0.4949	0.3203	1.19280	4.1858	0.8698	1.17824	2.13780
7	1	2	4.1109	0.4675	0.6183	3.02510	6.7408	1.2369	2.55736	2.94645
7	2	2	4.6615	0.7023	0.4389	3.52038	6.6334	1.4344	2.25960	2.93940
7	3	2	2.4303	0.3996	0.4195	1.61120	4.9188	1.1459	2.21536	1.55760
7	1	3	5.2119	0.8647	1.0304	3.31681	13.9778	3.1624	7.62355	3.19186
7	2	3	4.9761	0.6277	0.7640	3.58436	11.7651	2.3782	6.43851	2.94840
7	3	3	3.2265	0.7160	0.8962	1.61424	12.7006	3.3158	7.94875	1.43604
7	1	4	4.4028	0.9528	1.4880	1.96192	11.9618	2.2750	7.48650	2.20032
7	2	4	5.0365	0.9387	1.0862	3.01150	13.7368	3.7972	8.46052	1.47900
7	3	4	3.8337	1.4433	1.4572	0.92316	13.1102	3.2329	8.90120	0.97608
8	1	1	3.7907	0.3270	0.2170	3.24668	4.4205	0.4473	0.52875	3.44448
8	2	1	3.4064	0.1421	0.1510	3.11328	4.1296	0.1992	0.38798	3.54240
8	3	1	2.8454	0.2928	0.3404	2.21220	3.5821	0.4339	0.85803	2.29020
8	1	2	4.0987	0.5628	0.2983	3.23755	4.7938	0.7619	0.83382	3.19813
8	2	2	3.3705	0.2047	0.1888	2.97700	3.6513	0.3363	0.39200	2.92305
8	3	2	2.3252	0.3570	0.3274	1.64084	3.3310	0.5605	1.09776	1.67276
8	1	3	4.7669	0.5986	0.8334	3.33489	5.2375	0.4453	1.78777	3.00441
8	2	3	3.6287	0.6201	0.7241	2.28446	4.1965	0.5282	1.62486	2.04340
8	3	3	2.6092	0.5076	0.5200	1.58160	3.1910	0.5334	1.22005	1.43760

Table B-2. Continued

TRT	REP	STAGE	TCA	CARO	CASH	CACO	TMG	MGRO	MGSH	MGCO
8	1	4	4.7658	1.00254	0.9687	2.79456	5.0117	0.51156	2.2681	2.23200
8	2	4	4.6322	1.08504	1.2415	2.30568	4.9033	0.84546	2.2300	1.82780
8	3	4	3.3731	0.88128	0.7638	1.72800	3.4953	0.65664	1.4759	1.36280
9	1	1	4.6768	0.86338	0.3430	3.47036	4.5300	0.86191	0.3462	3.32189
9	2	1	4.6236	1.16280	0.3276	3.13320	4.7340	1.14228	0.2674	3.32430
9	3	1	3.6550	0.98658	0.2244	2.44400	3.4682	1.03518	0.2724	2.16060
9	1	2	6.3254	1.18959	2.1195	3.01636	5.0035	1.25343	1.1717	2.57836
9	2	2	11.0595	1.66498	1.9929	7.40160	5.6761	1.51143	1.0975	3.06720
9	3	2	8.1489	1.75562	2.8768	3.51648	5.5734	1.85320	1.7287	1.99152
9	1	3	17.1273	6.95856	5.0943	5.07440	11.5112	7.49448	1.3451	2.67160
9	2	3	35.0099	8.48040	22.4906	4.03886	18.0638	8.23990	7.4602	2.36368
9	3	3	24.4586	6.24346	14.6899	3.52520	15.1179	8.25824	5.0097	1.84996
9	1	4	44.5488	7.94708	31.9226	4.67908	18.6269	5.80720	10.2952	2.52450
9	2	4	42.7029	8.36767	31.2496	3.08568	16.2838	5.48857	9.0833	1.71192
9	3	4	30.1071	8.33416	17.7153	4.05768	17.0743	9.24464	5.5793	2.25040
10	1	1	3.7028	0.41517	0.2956	2.99200	4.2410	0.61047	0.7282	2.90240
10	2	1	3.6610	0.20162	0.1772	3.28224	4.1748	0.34102	0.4930	3.34080
10	3	1	2.6847	0.18900	0.2449	2.25085	3.0853	0.27450	0.5593	2.25144
10	1	2	3.5376	0.59866	0.3957	2.54322	4.4502	0.75998	1.0540	2.63623
10	2	2	3.4879	0.33415	0.2516	2.90213	4.1463	0.45756	0.6696	3.01917
10	3	2	2.6406	0.29964	0.2499	2.09100	2.9432	0.32934	0.6758	1.93800
10	1	3	3.5249	0.63551	0.7366	2.15280	4.2604	0.54281	1.7540	1.96360
10	2	3	3.4800	0.46980	0.6495	2.36070	4.0662	0.40824	1.4632	2.19472
10	3	3	1.8242	0.35320	0.4672	1.00380	2.0670	0.34960	0.7576	0.95980
10	1	4	4.0396	1.13700	0.7206	2.18196	4.2245	0.80200	1.4112	2.01132
10	2	4	4.3320	1.01158	1.3234	1.99702	4.4463	0.66304	1.9483	1.83489
10	3	4	2.2459	0.80914	0.4957	0.94104	2.4159	0.50876	0.8969	1.01016

Table B-2. Continued

TRT	REP	STAGE	TMN	MNRO	MNSH	MNCO	TB	BRO	BSH	BCO
1	1	1	56.470	7.15	10.920	38.40	62.120	10.40	17.160	34.56
1	2	1	54.331	4.48	6.531	43.32	48.952	4.80	9.952	34.20
1	3	1	37.990	3.90	6.210	27.88	37.070	5.85	8.100	23.12
1	1	2	62.710	6.12	8.740	47.85	56.490	7.48	13.340	35.67
1	2	2	56.930	11.57	11.550	33.81	59.320	12.46	16.500	30.36
1	3	2	38.340	4.68	10.200	23.46	41.480	6.76	16.320	18.40
1	1	3	88.440	10.95	49.770	27.72	90.600	21.90	52.140	16.56
1	2	3	87.410	12.24	42.780	32.39	90.520	20.40	52.080	18.04
1	3	3	80.960	19.58	36.960	24.42	61.070	11.57	35.640	13.86
1	1	4	184.660	40.50	124.690	19.47	168.960	35.10	121.320	12.54
1	2	4	92.430	21.69	52.440	18.30	104.240	19.28	72.960	12.00
1	3	4	112.140	30.03	70.380	11.73	80.180	17.16	53.820	9.20
2	1	1	46.050	4.00	6.000	36.05	51.420	6.50	9.900	35.02
2	2	1	45.290	4.77	7.840	32.68	47.620	7.42	9.240	30.96
2	3	1	25.860	1.98	8.580	15.30	29.430	4.29	7.800	17.34
2	1	2	46.460	5.58	10.080	30.80	50.100	9.92	12.180	28.00
2	2	2	44.300	4.64	10.260	29.40	47.060	6.96	11.400	28.70
2	3	2	31.590	3.15	9.240	19.20	28.540	4.50	9.240	14.80
2	1	3	60.960	11.88	24.480	24.60	60.230	14.85	21.600	23.78
2	2	3	51.010	8.94	21.420	20.65	62.400	17.88	27.370	17.15
2	3	3	42.610	10.90	15.960	15.75	37.590	13.08	11.760	12.75
2	1	4	62.100	16.44	24.960	20.70	58.680	16.44	23.040	19.20
2	2	4	70.930	22.45	32.880	15.60	57.370	17.96	23.290	16.12
2	3	4	55.310	17.05	22.420	15.84	49.880	20.46	15.340	14.08
3	1	1	46.860	2.64	7.260	36.96	51.020	4.62	10.560	35.84
3	2	1	38.700	2.10	4.200	32.40	51.780	6.30	5.880	39.60
3	3	1	27.410	4.14	6.930	16.34	25.420	4.60	7.920	12.90
3	1	2	51.040	5.88	6.760	38.40	47.300	6.86	7.800	32.64
3	2	2	44.830	8.00	8.880	27.95	43.470	11.20	11.470	20.80
3	3	2	31.710	4.95	10.360	16.40	32.420	6.60	11.470	14.35
3	1	3	54.300	6.00	18.620	29.68	56.850	12.00	17.290	27.56

Table B-2. Continued

TRT	REP	STAGE	TMN	MNRO	MNSH	MNCO	TB	BRO	BSH	BCO
3	2	3	42.35	8.28	14.96	19.11	39.18	9.20	13.60	16.38
3	3	3	43.78	14.48	16.80	12.50	36.67	12.67	12.00	12.00
3	1	4	62.40	12.18	25.80	24.42	60.37	18.27	20.64	21.46
3	2	4	54.85	6.48	29.82	18.55	54.68	8.10	26.98	19.60
3	3	4	54.69	15.54	26.39	12.76	46.65	17.76	15.47	13.42
4	1	1	51.00	6.93	8.58	35.49	45.21	5.61	9.57	30.03
4	2	1	52.32	6.60	7.02	38.70	40.32	6.00	5.94	28.38
4	3	1	46.62	7.80	6.48	32.34	38.88	6.63	7.83	24.42
4	1	2	60.78	12.60	8.58	39.60	49.20	7.80	9.90	31.50
4	2	2	54.18	10.26	10.92	33.00	40.26	5.94	10.92	23.40
4	3	2	40.06	5.17	10.89	24.00	34.27	6.58	10.89	16.80
4	1	3	63.74	12.24	27.82	23.68	49.38	10.88	19.26	19.24
4	2	3	67.60	14.00	26.40	27.20	63.80	9.00	30.40	24.40
4	3	3	61.63	17.25	28.32	16.06	41.83	10.35	16.52	14.96
4	1	4	57.83	9.73	27.94	20.16	53.85	9.73	25.40	18.72
4	2	4	59.45	15.84	19.04	24.57	65.48	16.83	27.20	21.45
4	3	4	71.44	25.02	32.85	13.57	41.36	16.68	13.87	10.81
5	1	1	57.90	6.12	7.92	43.86	54.66	7.56	9.36	37.74
5	2	1	64.88	5.92	9.24	49.72	59.00	7.40	10.92	40.68
5	3	1	51.28	7.99	11.47	31.82	51.31	9.87	14.06	27.38
5	1	2	59.89	7.82	14.00	38.07	54.43	9.66	14.80	29.97
5	2	2	48.82	6.72	11.10	31.00	45.60	11.20	13.32	21.08
5	3	2	39.99	7.59	11.60	20.80	44.71	13.11	14.40	17.20
5	1	3	85.00	10.80	50.60	23.60	101.80	21.60	59.80	20.40
5	2	3	62.28	7.68	23.92	30.68	73.92	11.52	36.40	26.00
5	3	3	57.94	9.04	33.50	15.40	65.44	15.82	36.18	13.44
5	1	4	73.47	11.62	37.76	24.09	95.37	19.92	56.64	18.81
5	2	4	72.18	10.96	34.02	27.20	97.40	19.18	50.22	28.00
5	3	4	55.68	12.06	26.82	16.80	67.94	22.78	29.80	15.36
6	1	1	59.18	5.88	10.50	42.80	56.61	7.98	12.25	36.38
6	2	1	49.90	6.30	8.00	35.60	48.19	7.65	8.50	32.04

Table B-2. Continued

TRT	REP	STAGE	TMN	MNRO	MNSH	MNCO	TB	BRO	BSH	BCO
6	3	1	42.92	5.40	8.96	28.56	44.19	8.55	9.80	25.84
6	1	2	57.61	8.64	19.72	29.25	63.77	15.36	21.76	26.65
6	2	2	48.58	4.72	12.18	31.68	54.72	10.62	13.86	30.24
6	3	2	40.58	8.00	12.90	19.68	43.00	11.20	13.76	18.04
6	1	3	59.33	6.03	32.06	21.24	97.92	18.09	61.83	18.00
6	2	3	59.80	8.16	34.24	17.40	100.55	20.40	64.20	15.95
6	3	3	52.30	16.80	20.16	15.34	74.58	21.00	40.32	13.26
6	1	4	76.74	19.20	35.70	21.84	109.90	22.40	69.02	18.48
6	2	4	109.06	47.79	39.52	21.75	126.81	26.55	81.51	18.75
6	3	4	87.01	20.25	45.60	21.16	103.72	24.75	60.80	18.17
7	1	1	64.82	6.29	10.56	47.97	60.83	7.40	12.48	40.95
7	2	1	48.14	6.56	7.54	34.04	48.56	8.20	10.92	29.44
7	3	1	43.16	8.64	9.92	24.60	43.64	8.64	12.80	22.20
7	1	2	48.99	4.40	16.64	27.95	50.47	7.70	16.12	26.65
7	2	2	45.93	6.57	11.76	27.60	49.93	11.68	11.34	26.91
7	3	2	37.10	4.32	15.18	17.60	38.96	7.56	13.80	17.60
7	1	3	61.09	5.55	30.06	25.48	88.69	16.65	45.09	26.95
7	2	3	52.88	9.72	18.72	24.44	80.11	11.34	38.61	30.16
7	3	3	49.24	6.24	25.00	18.00	70.09	14.04	36.25	19.80
7	1	4	79.81	12.45	44.64	22.72	70.07	14.11	40.92	15.04
7	2	4	58.98	6.64	19.84	32.50	82.01	14.11	43.40	24.50
7	3	4	47.56	6.96	21.00	19.60	67.49	16.53	37.80	13.16
8	1	1	41.69	5.83	5.50	30.36	45.22	6.36	8.50	30.36
8	2	1	42.39	2.88	3.99	35.52	43.71	2.88	6.27	34.56
8	3	1	33.71	4.80	8.51	20.40	37.78	7.20	12.58	18.00
8	1	2	47.13	10.08	8.58	28.47	52.89	10.92	11.31	30.66
8	2	2	35.10	3.40	4.40	27.30	35.20	3.40	5.80	26.00
8	3	2	31.18	6.00	9.60	15.58	37.54	7.00	13.44	17.10
8	1	3	55.37	8.03	21.33	26.01	54.90	10.95	18.96	24.99
8	2	3	42.09	8.08	17.01	17.00	52.83	8.08	26.73	18.02
8	3	3	37.41	10.80	13.65	12.96	34.29	8.40	13.65	12.24

Table B-2. Continued

TRT	REP	STAGE	TMN	MNRO	MNSH	MNCO	TB	BRO	ESH	BCO
8	1	4	65.70	13.23	29.75	22.72	58.74	11.76	26.18	20.80
8	2	4	51.86	11.88	21.78	18.20	66.19	15.84	32.67	17.68
8	3	4	42.59	11.52	15.87	15.20	40.56	10.80	16.56	13.20
9	1	1	42.32	4.41	2.56	35.35	43.10	5.88	2.88	34.34
9	2	1	46.97	5.32	2.80	38.85	47.62	9.12	2.80	35.70
9	3	1	32.07	4.32	2.40	25.35	31.98	5.94	2.64	23.40
9	1	2	45.63	5.13	12.76	27.74	46.03	6.84	13.64	25.55
9	2	2	58.00	9.13	12.87	36.00	51.38	8.30	12.48	30.60
9	3	2	46.96	8.20	17.70	21.06	47.52	9.84	17.70	19.98
9	1	3	49.45	8.40	7.05	34.00	40.06	11.76	4.70	23.60
9	2	3	99.72	14.80	55.00	29.92	72.92	18.50	33.00	21.42
9	3	3	71.70	10.48	37.70	23.52	50.34	11.79	21.75	16.80
9	1	4	84.56	9.76	47.60	27.20	68.76	17.08	30.60	21.08
9	2	4	86.14	9.14	57.80	19.20	79.15	22.85	40.46	15.84
9	3	4	80.63	10.64	45.92	24.07	46.13	13.68	14.76	17.69
10	1	1	45.12	6.93	7.79	30.40	50.16	9.45	12.71	28.00
10	2	1	43.76	3.40	5.80	34.56	46.78	5.44	8.70	32.64
10	3	1	30.18	3.00	5.94	21.24	35.39	5.10	10.23	20.06
10	1	2	45.23	10.36	11.44	23.43	53.85	11.84	17.16	24.85
10	2	2	39.07	5.33	7.56	26.18	44.57	5.74	11.88	26.95
10	3	2	28.39	3.63	6.40	18.36	32.66	4.95	10.88	16.83
10	1	3	49.83	10.30	19.53	20.00	56.97	15.45	22.32	19.20
10	2	3	42.49	5.67	15.75	21.07	55.57	7.29	28.50	19.78
10	3	3	23.80	4.80	9.60	9.40	23.60	4.00	10.80	8.80
10	1	4	50.44	16.00	15.36	19.08	46.00	11.00	16.64	18.36
10	2	4	44.41	8.14	20.46	15.81	56.00	8.88	31.62	15.50
10	3	4	25.54	7.36	9.18	9.00	26.62	7.36	10.80	8.46

Table B-2. Continued

TRT	REP	STAGE	TAL	ALRO	ALSH	ALCO	TCU	CURO	CUSH	CUCO
1	1	1	109.150	79.95	17.680	11.52	32.890	11.05	9.360	12.48
1	2	1	64.723	41.92	10.263	12.54	22.627	4.80	5.287	12.54
1	3	1	64.240	47.58	9.180	7.48	18.060	5.85	4.050	8.16
1	1	2	171.490	133.28	14.720	23.49	24.610	9.52	5.520	9.57
1	2	2	203.130	167.32	19.250	16.56	27.950	13.35	7.700	6.90
1	3	2	140.990	111.28	16.830	12.88	17.830	6.24	5.610	5.98
1	1	3	539.520	451.14	71.100	17.28	42.090	17.52	21.330	3.24
1	2	3	396.810	289.68	91.140	15.99	43.510	20.40	18.600	4.51
1	3	3	178.930	113.92	51.480	13.53	29.190	13.35	11.880	3.96
1	1	4	353.220	199.80	141.540	11.88	127.400	56.70	67.400	3.30
1	2	4	325.100	236.18	77.520	11.40	23.740	9.64	11.400	2.70
1	3	4	201.350	134.42	60.030	6.90	24.730	10.01	12.420	2.30
2	1	1	56.000	38.50	7.200	10.30	28.060	10.00	5.700	12.36
2	2	1	56.890	38.69	6.160	12.04	22.960	8.48	5.880	8.60
2	3	1	35.460	23.10	6.240	6.12	16.230	5.94	4.680	5.61
2	1	2	87.680	66.96	10.920	9.80	30.840	14.88	7.560	8.40
2	2	2	84.120	63.80	9.120	11.20	20.100	6.96	6.840	6.30
2	3	2	67.730	53.55	8.580	5.60	15.820	7.20	4.620	4.00
2	1	3	644.940	605.88	31.680	7.38	35.730	11.88	20.160	3.69
2	2	3	546.830	515.54	24.990	6.30	34.960	17.88	14.280	2.80
2	3	3	412.610	390.22	17.640	4.75	31.700	21.80	8.400	1.50
2	1	4	856.530	785.01	59.520	12.00	48.150	28.77	17.280	2.10
2	2	4	777.250	727.38	39.730	10.14	30.620	13.47	15.070	2.08
2	3	4	642.040	579.70	53.100	9.24	20.990	10.23	9.440	1.32
3	1	1	60.170	34.65	13.200	12.32	27.430	5.94	6.930	14.56
3	2	1	59.040	37.80	9.240	12.00	26.810	5.60	4.410	16.80
3	3	1	63.830	46.00	13.530	4.30	19.980	7.36	6.600	6.02
3	1	2	81.370	58.31	9.620	13.44	31.620	11.76	5.460	14.40
3	2	2	110.950	86.40	14.800	9.75	34.100	17.60	7.400	9.10
3	3	2	88.910	69.85	13.320	5.74	22.950	11.00	7.030	4.92
3	1	3	496.030	424.80	55.860	15.37	38.990	18.00	14.630	6.36

Table B-2. Continued

TRT	REP	STAGE	TAL	ALRO	ALSH	ALCO	TCU	CURO	CUSH	CUCO
3	2	3	292.01	249.32	30.60	12.09	24.70	11.96	8.84	3.90
3	3	3	501.27	456.12	38.40	6.75	25.02	12.67	9.60	2.75
3	1	4	739.43	659.75	61.92	17.76	26.19	8.12	15.48	2.59
3	2	4	352.51	294.84	44.02	13.65	19.89	3.24	14.20	2.45
3	3	4	669.95	628.26	30.03	11.66	19.23	11.10	6.37	1.76
4	1	1	67.19	40.59	13.86	12.74	26.76	8.25	7.59	10.92
4	2	1	62.54	36.90	11.88	13.76	23.46	7.20	5.94	10.32
4	3	1	72.12	49.92	12.96	9.24	24.78	10.14	5.40	9.24
4	1	2	104.40	72.60	16.50	15.30	31.47	12.60	6.27	12.60
4	2	2	114.72	74.52	23.40	16.80	29.28	11.88	7.80	9.60
4	3	2	100.00	66.74	20.46	12.80	18.87	8.46	5.61	4.80
4	1	3	366.25	248.88	77.04	40.33	36.89	14.96	17.12	4.81
4	2	3	278.60	193.00	37.60	48.00	39.60	18.00	15.20	6.40
4	3	3	225.43	166.29	31.86	27.28	34.60	24.15	6.49	3.96
4	1	4	496.24	436.46	48.26	11.52	40.00	18.07	19.05	2.88
4	2	4	375.81	325.71	30.60	19.50	38.52	22.77	12.24	3.51
4	3	4	369.00	322.48	26.28	20.24	28.07	20.85	5.84	1.38
5	1	1	88.56	53.64	16.56	18.36	30.12	9.00	4.80	16.32
5	2	1	94.04	55.50	18.20	20.34	30.58	8.88	5.88	15.82
5	3	1	104.68	67.68	24.42	12.58	29.04	11.28	8.14	9.62
5	1	2	100.07	63.48	21.20	15.39	30.36	11.04	9.60	9.72
5	2	2	129.13	93.52	18.87	16.74	27.72	12.88	7.40	7.44
5	3	2	145.41	116.61	20.00	8.80	25.40	13.80	7.20	4.40
5	1	3	625.00	498.00	105.80	21.20	70.30	26.40	39.10	4.80
5	2	3	270.12	184.32	61.36	24.44	33.12	14.40	13.52	5.20
5	3	3	259.47	177.41	68.34	13.72	29.62	15.82	10.72	3.08
5	1	4	351.14	204.18	129.80	17.16	43.17	16.60	23.60	2.97
5	2	4	672.84	561.70	92.34	18.80	29.54	10.96	14.58	4.00
5	3	4	500.82	443.54	47.68	9.60	19.08	10.72	5.96	2.40
6	1	1	87.81	52.08	15.40	20.33	33.28	13.44	7.00	12.84
6	2	1	79.39	54.90	10.25	14.24	30.59	15.30	5.50	9.79

Table B-2. Continued

TRT	REP	STAGE	TAL	ALRO	ALSH	ALCO	TCU	CURO	CUSH	CUCO
6	3	1	84.14	58.50	12.04	13.60	25.90	13.50	5.60	6.80
6	1	2	187.44	137.28	31.96	18.20	36.33	16.32	11.56	8.45
6	2	2	146.14	110.92	17.22	18.00	26.23	10.03	7.56	8.64
6	3	2	164.39	133.60	18.49	12.30	21.32	11.20	6.02	4.10
6	1	3	534.58	422.10	91.60	20.88	52.47	22.11	27.48	2.68
6	2	3	516.39	395.76	107.00	13.63	52.10	20.40	29.96	1.74
6	3	3	369.36	312.90	43.20	13.26	30.66	16.80	11.52	2.34
6	1	4	759.88	633.60	109.48	16.80	50.26	22.40	26.18	1.68
6	2	4	801.78	695.61	88.92	17.25	39.91	15.93	22.23	1.75
6	3	4	496.00	402.75	76.00	17.25	24.03	11.25	11.40	1.38
7	1	1	121.68	72.15	24.96	24.57	35.48	11.10	8.00	16.38
7	2	1	127.11	82.41	22.62	22.08	32.25	13.53	6.76	11.96
7	3	1	132.52	91.20	22.72	18.60	27.68	13.44	7.04	7.20
7	1	2	153.43	100.65	33.28	19.50	30.79	11.55	8.84	10.40
7	2	2	198.51	142.35	28.56	27.60	33.40	16.06	6.30	11.04
7	3	2	134.14	96.12	21.62	16.40	22.84	10.80	6.44	5.60
7	1	3	423.13	308.58	76.82	37.73	46.51	24.42	16.70	5.39
7	2	3	335.79	231.66	66.69	37.44	41.11	21.87	14.04	5.20
7	3	3	278.96	205.14	42.50	31.32	28.71	11.70	11.25	5.76
7	1	4	464.46	249.00	195.30	20.16	22.66	8.30	11.16	3.20
7	2	4	440.63	264.77	141.36	34.50	26.53	9.13	12.40	5.00
7	3	4	343.70	231.42	92.40	19.88	19.96	10.44	7.00	2.52
8	1	1	93.47	66.25	12.50	14.72	26.75	9.54	5.25	11.96
8	2	1	55.09	31.20	10.45	13.44	18.20	3.84	3.80	10.56
8	3	1	90.63	60.96	18.87	10.80	23.74	9.60	8.14	6.00
8	1	2	179.49	130.20	23.01	26.28	38.91	20.16	7.80	10.95
8	2	2	88.61	52.36	12.20	24.05	21.38	7.48	4.80	9.10
8	3	2	124.68	84.50	26.88	13.30	24.14	9.50	10.08	4.56
8	1	3	312.30	229.95	63.99	18.36	40.17	18.25	15.80	6.12
8	2	3	223.87	185.84	25.11	12.92	42.36	23.23	15.39	3.74
8	3	3	122.54	82.80	29.90	9.84	23.45	12.60	8.45	2.40

Table B-2. Continued

TRT	REP	STAGE	TAL	ALRO	ALSH	ALCO	TCU	CURO	CUSH	CUCO
8	1	4	483.89	411.60	51.17	21.12	38.01	19.11	16.66	2.24
8	2	4	849.32	799.92	31.46	17.94	31.49	15.84	13.31	2.34
8	3	4	207.06	164.88	28.98	13.20	19.59	10.80	7.59	1.20
9	1	1	65.45	58.80	1.60	5.05	28.30	14.21	0.96	13.13
9	2	1	100.89	94.24	1.40	5.25	36.59	22.80	2.24	11.55
9	3	1	69.06	63.72	1.44	3.90	25.86	15.66	2.40	7.80
9	1	2	77.63	57.57	12.76	7.30	26.21	10.26	7.92	8.03
9	2	2	119.47	98.77	11.70	9.00	30.96	14.94	7.02	9.00
9	3	2	114.43	90.20	18.29	5.94	31.09	13.94	11.21	5.94
9	1	3	351.48	320.88	9.40	21.20	31.74	21.84	4.70	5.20
9	2	3	689.04	566.10	105.60	17.34	44.92	18.50	22.00	4.42
9	3	3	305.92	233.18	55.10	17.64	28.34	10.48	14.50	3.36
9	1	4	804.60	656.36	119.00	29.24	46.32	17.08	27.20	2.04
9	2	4	965.08	840.88	104.04	20.16	35.86	13.71	20.23	1.92
9	3	4	283.83	208.24	49.20	26.39	36.26	19.76	14.76	1.74
10	1	1	85.84	56.70	13.94	15.20	31.42	13.23	7.79	10.40
10	2	1	58.68	29.24	9.28	20.16	24.12	6.80	5.80	11.52
10	3	1	48.57	26.40	11.55	10.62	19.98	6.30	6.60	7.08
10	1	2	112.86	87.32	15.60	9.94	41.34	22.94	9.88	8.52
10	2	2	70.69	44.69	13.68	12.32	27.20	12.30	7.20	7.70
10	3	2	55.19	37.62	9.92	7.65	22.25	10.56	6.08	5.61
10	1	3	273.52	210.12	55.80	7.60	44.60	22.66	16.74	5.20
10	2	3	157.49	109.35	38.25	9.89	48.62	28.35	14.25	6.02
10	3	3	79.80	60.80	15.20	3.80	20.00	10.40	7.20	2.40
10	1	4	227.48	175.00	40.96	11.52	50.60	30.00	16.64	3.96
10	2	4	160.21	125.80	24.18	10.23	28.15	11.10	13.95	3.10
10	3	4	110.86	73.60	31.86	5.40	11.18	5.06	4.32	1.80

Table B-2. Continued

TRT	REP	STAGE	TFE	FERO	FESH	FECO	TNA	NARO	NASH	NACO
1	1	1	200.25	81.25	43.16	75.84	154.21	83.85	47.320	23.04
1	2	1	151.98	41.60	24.88	85.50	96.60	43.84	27.679	25.08
1	3	1	120.08	46.80	21.60	51.68	86.98	47.58	23.760	15.64
1	1	2	164.91	71.40	31.74	61.77	317.74	251.60	24.380	41.76
1	2	2	180.21	89.00	40.15	51.06	378.99	313.28	31.900	33.81
1	3	2	118.91	50.96	36.21	31.74	241.23	190.84	26.010	24.38
1	1	3	418.14	232.14	161.16	24.84	1812.81	1655.64	144.570	12.60
1	2	3	333.97	187.68	117.18	29.11	1686.74	1560.60	109.740	16.40
1	3	3	219.49	111.25	85.80	22.44	167.90	91.67	63.360	12.87
1	1	4	518.77	170.10	326.89	21.78	529.67	329.40	188.720	11.55
1	2	4	360.03	209.67	129.96	20.40	759.84	636.24	114.000	9.60
1	3	4	295.73	163.02	117.99	14.72	324.50	235.95	78.660	9.89
2	1	1	126.53	30.00	23.40	73.13	181.04	115.50	26.400	39.14
2	2	1	117.56	36.04	19.60	61.92	198.90	137.80	22.400	38.70
2	3	1	75.36	23.76	17.94	33.66	130.04	83.49	20.540	26.01
2	1	2	134.96	47.74	31.92	55.30	264.96	194.68	31.080	39.20
2	2	2	134.36	53.36	28.50	52.50	246.24	185.02	26.220	35.00
2	3	2	96.49	39.60	24.09	32.80	189.13	144.45	25.080	19.60
2	1	3	585.63	430.65	118.08	36.90	1401.62	1348.38	41.760	11.48
2	2	3	459.73	315.88	113.05	30.80	541.77	503.62	29.750	8.40
2	3	3	360.45	265.96	72.24	22.25	286.79	252.88	20.160	13.75
2	1	4	831.03	645.27	159.36	26.40	1131.78	1076.82	44.160	10.80
2	2	4	906.88	758.81	124.67	23.40	540.44	498.39	34.250	7.80
2	3	4	588.40	443.30	125.08	20.02	1340.34	1302.62	30.680	7.04
3	1	1	135.36	27.39	30.69	77.28	238.43	94.38	91.410	52.64
3	2	1	127.61	25.55	18.06	84.00	210.81	100.80	54.810	55.20
3	3	1	91.79	33.12	32.01	26.66	239.83	128.80	89.100	21.93
3	1	2	145.27	42.63	23.92	78.72	241.08	144.06	41.340	55.68
3	2	2	157.36	72.80	32.56	52.00	351.05	252.80	70.300	27.95
3	3	2	118.88	55.00	31.08	32.80	288.26	216.70	51.060	20.50
3	1	3	373.18	224.40	101.08	47.70	855.75	782.40	55.860	17.49

Table B-2. Continued

TRT	REP	STAGE	TFE	FERO	FESH	FECO	TNA	NARO	NASH	NACO
3	2	3	260.81	169.28	59.16	32.37	277.34	249.32	16.32	11.70
3	3	3	276.54	179.19	77.60	19.75	464.52	438.02	20.00	6.50
3	1	4	498.37	339.01	123.84	35.52	1568.54	1498.14	37.84	32.56
3	2	4	437.62	281.88	123.54	32.20	297.31	223.56	42.60	31.15
3	3	4	559.33	450.66	86.45	22.22	740.37	692.64	26.39	21.34
4	1	1	129.13	35.31	27.39	66.43	130.58	88.11	18.81	23.66
4	2	1	130.73	29.40	25.65	75.68	137.08	92.70	19.44	24.94
4	3	1	134.64	48.36	27.54	58.74	160.77	112.32	24.03	24.42
4	1	2	184.29	78.00	30.69	75.60	425.16	289.80	43.56	91.80
4	2	2	197.28	101.52	40.56	55.20	372.78	269.46	49.92	53.40
4	3	2	175.63	92.12	41.91	41.60	291.56	208.68	44.88	38.00
4	1	3	549.20	326.40	176.55	46.25	904.91	779.28	113.42	12.21
4	2	3	409.60	262.00	96.00	51.60	522.20	457.00	48.80	16.40
4	3	3	330.11	213.90	86.73	29.48	273.21	238.74	26.55	7.92
4	1	4	627.87	394.76	184.15	48.96	1142.92	1018.87	95.25	28.80
4	2	4	542.21	396.99	94.52	50.70	668.52	598.95	38.76	30.81
4	3	4	545.19	365.57	146.73	32.89	441.86	394.76	28.47	18.63
5	1	1	137.52	36.36	21.60	79.56	141.06	77.76	27.60	35.70
5	2	1	149.00	38.48	24.64	85.88	153.48	78.07	33.60	41.81
5	3	1	135.03	45.12	33.67	56.24	162.48	95.88	42.18	24.42
5	1	2	136.71	36.34	38.00	62.37	173.45	103.50	41.60	28.35
5	2	2	136.78	54.88	34.78	47.12	208.62	145.60	40.70	22.32
5	3	2	146.26	78.66	36.80	30.80	228.87	167.67	45.60	15.60
5	1	3	484.30	276.00	177.10	31.20	634.90	324.00	292.10	18.80
5	2	3	214.08	114.24	62.40	37.44	315.80	172.80	118.56	24.44
5	3	3	216.53	114.13	83.08	19.32	409.89	267.81	128.64	13.44
5	1	4	744.38	552.78	165.20	26.40	1270.81	808.42	438.96	23.43
5	2	4	445.95	283.59	126.36	36.00	611.30	394.56	189.54	27.20
5	3	4	429.86	344.38	65.56	19.92	542.93	296.14	230.95	15.84
6	1	1	144.50	39.48	29.05	75.97	168.78	89.04	45.50	34.24
6	2	1	128.20	45.90	20.00	62.30	157.20	99.00	31.50	26.70

Table B-2. Continued

TRT	REP	STAGE	TFE	FERO	FESH	FECO	TNA	NARO	NASH	NACO
6	3	1	116.36	45.00	22.40	48.96	184.28	127.80	34.72	21.76
6	1	2	200.67	96.96	52.36	51.35	383.99	290.88	62.56	30.55
6	2	2	158.42	66.08	34.02	58.32	310.31	234.23	43.68	32.40
6	3	2	156.41	88.00	33.97	34.44	383.36	323.20	41.71	18.45
6	1	3	613.21	373.86	208.39	30.96	1041.69	924.60	103.05	14.04
6	2	3	539.10	306.00	207.58	25.52	829.73	754.80	64.20	10.73
6	3	3	405.98	275.10	108.00	22.88	469.50	403.20	56.16	10.14
6	1	4	755.32	544.00	185.64	25.68	1043.78	947.20	73.78	22.80
6	2	4	818.31	573.48	219.83	25.00	1488.34	1369.98	93.86	24.50
6	3	4	501.26	333.00	142.50	25.76	342.49	256.50	64.60	21.39
7	1	1	185.80	53.28	34.24	98.28	193.26	107.30	43.84	42.12
7	2	1	167.24	64.78	28.86	73.60	185.20	117.26	36.66	31.28
7	3	1	151.24	68.16	33.28	49.80	206.32	138.72	44.80	22.80
7	1	2	155.62	55.00	49.92	50.70	245.80	163.90	62.40	19.50
7	2	2	163.08	72.27	39.06	51.75	287.52	216.81	52.08	18.63
7	3	2	126.56	50.22	45.54	30.80	224.60	156.60	55.20	12.80
7	1	3	273.85	139.86	91.85	42.14	568.30	223.11	300.60	44.59
7	2	3	231.75	118.26	71.37	42.12	444.86	168.48	231.66	44.72
7	3	3	233.08	135.72	70.00	27.36	360.30	109.98	210.00	40.32
7	1	4	394.72	210.82	161.82	22.08	450.82	234.06	174.84	41.92
7	2	4	225.44	114.54	74.40	36.50	447.84	190.90	193.44	63.50
7	3	4	267.40	146.16	102.20	19.04	386.32	208.80	140.00	37.52
8	1	1	136.06	53.00	20.50	62.56	247.57	109.18	76.75	61.64
8	2	1	100.24	23.04	16.72	60.48	153.54	51.84	60.42	41.28
8	3	1	122.12	49.92	29.60	42.60	277.22	108.00	120.62	48.60
8	1	2	211.94	118.44	35.10	58.40	476.32	355.32	65.52	55.48
8	2	2	119.70	47.60	18.80	53.30	237.46	139.06	38.60	59.80
8	3	2	148.98	72.00	48.48	28.50	370.98	220.00	102.72	48.26
8	1	3	359.82	193.45	108.23	58.14	384.16	286.16	75.05	22.95
8	2	3	418.43	275.73	105.30	37.40	345.49	275.73	46.98	22.78
8	3	3	195.45	106.20	60.45	28.80	307.39	246.00	38.35	23.04

Table B-2. Continued

TRT	REP	STAGE	TFE	FERO	FESH	FECO	TNA	NARO	NASH	NACO
8	1	4	629.23	413.07	171.36	44.80	629.78	488.04	59.50	82.24
8	2	4	613.13	459.36	117.37	36.40	744.93	421.74	279.51	43.68
8	3	4	285.04	172.08	85.56	27.40	403.71	313.92	48.99	40.80
9	1	1	112.14	33.81	8.64	69.69	59.85	55.86	0.96	3.03
9	2	1	139.23	53.20	11.48	74.55	93.67	89.68	0.84	3.15
9	3	1	94.36	41.04	9.12	44.20	63.07	58.86	0.96	3.25
9	1	2	121.61	36.48	34.76	50.37	56.52	53.01	1.32	2.19
9	2	2	151.06	58.93	30.03	62.10	86.48	83.00	0.78	2.70
9	3	2	151.73	65.60	47.79	38.34	84.83	80.36	1.77	2.70
9	1	3	222.04	146.16	39.48	36.40	1287.41	1285.20	1.41	0.80
9	2	3	562.40	288.60	239.80	34.00	1680.62	1576.20	103.40	1.02
9	3	3	303.25	116.59	159.50	27.16	308.58	243.66	63.80	1.12
9	1	4	498.34	258.64	210.80	28.90	976.56	805.20	146.20	25.16
9	2	4	635.21	402.15	210.97	22.08	1570.99	1434.98	118.49	17.52
9	3	4	301.44	161.12	114.80	25.52	284.64	205.20	57.40	22.04
10	1	1	160.04	63.63	33.21	63.20	236.07	190.26	25.01	20.80
10	2	1	132.84	34.00	22.04	76.80	148.63	105.40	18.27	24.96
10	3	1	107.79	33.60	26.40	47.79	127.74	91.80	21.78	14.16
10	1	2	185.23	85.84	44.72	54.67	477.40	389.24	54.08	34.08
10	2	2	137.86	49.20	31.68	56.98	316.70	246.82	36.00	33.88
10	3	2	108.78	40.26	29.76	38.76	249.42	191.40	34.56	23.46
10	1	3	379.62	219.39	121.83	38.40	485.98	381.10	89.28	15.60
10	2	3	266.88	142.56	81.75	42.57	706.58	623.70	65.25	17.63
10	3	3	125.20	57.60	47.60	20.00	326.80	266.00	52.80	8.00
10	1	4	369.40	253.00	76.80	39.60	207.36	142.00	41.60	23.76
10	2	4	303.15	177.60	91.14	34.41	623.91	572.76	30.69	20.46
10	3	4	195.60	113.16	62.64	19.80	315.54	211.14	91.80	12.60

Table B-2. Continued

TRT	REP	STAGE	TZN	ZNRO	ZNSH	ZNCO
1	1	1	93.970	26.65	32.760	34.56
1	2	1	74.402	14.08	19.282	41.04
1	3	1	52.980	16.38	16.200	20.40
1	1	2	53.010	12.24	13.800	26.97
1	2	2	58.710	19.58	17.050	22.08
1	3	2	45.460	12.48	17.340	15.64
1	1	3	103.470	24.09	71.100	8.28
1	2	3	100.780	30.60	59.520	10.66
1	3	3	69.310	20.47	40.920	7.92
1	1	4	384.190	148.50	225.790	9.90
1	2	4	77.830	16.87	50.160	10.80
1	3	4	107.510	35.75	64.170	7.59
2	1	1	78.310	22.50	17.700	38.11
2	2	1	66.350	21.73	16.240	28.38
2	3	1	47.260	12.54	15.340	19.38
2	1	2	97.820	32.86	41.160	23.80
2	2	2	83.620	24.36	36.860	22.40
2	3	2	58.770	16.20	29.370	13.20
2	1	3	98.960	35.64	51.840	11.48
2	2	3	120.320	56.62	53.550	10.15
2	3	3	82.860	41.42	34.440	7.00
2	1	4	94.860	32.88	55.680	6.30
2	2	4	89.680	26.94	57.540	5.20
2	3	4	125.480	68.20	53.100	4.18
3	1	1	77.470	14.85	17.820	44.80
3	2	1	79.740	16.80	11.340	51.60
3	3	1	51.670	18.40	16.500	16.77
3	1	2	78.290	24.99	15.860	37.44
3	2	2	90.610	40.00	23.310	27.30
3	3	2	58.730	25.30	20.720	12.71
3	1	3	92.330	33.60	43.890	14.84

Table B-2. Continued

TRT	REP	STAGE	TZN	ZNRO	ZNSH	ZNCO
3	2	3	74.78	34.04	30.60	10.14
3	3	3	106.60	45.25	53.60	7.75
3	1	4	96.83	30.45	56.76	9.62
3	2	4	77.86	16.20	53.96	7.70
3	3	4	66.00	26.64	32.76	6.60
4	1	1	73.60	22.11	17.82	33.67
4	2	1	71.96	18.90	13.50	39.56
4	3	1	66.69	26.91	14.04	25.74
4	1	2	83.37	32.40	19.47	31.50
4	2	2	69.42	23.22	23.40	22.80
4	3	2	44.53	14.57	17.16	12.80
4	1	3	101.58	44.88	47.08	9.62
4	2	3	114.00	46.00	52.00	16.00
4	3	3	76.71	36.57	30.68	9.46
4	1	4	93.88	33.36	50.80	9.72
4	2	4	139.93	78.21	52.36	9.36
4	3	4	110.79	62.55	40.88	7.36
5	1	1	89.46	27.00	16.56	45.90
5	2	1	95.33	29.97	20.16	45.20
5	3	1	92.63	37.13	24.42	31.08
5	1	2	112.84	43.24	37.20	32.40
5	2	2	105.86	52.08	29.60	24.18
5	3	2	110.90	62.10	33.20	15.60
5	1	3	143.10	43.20	85.10	14.80
5	2	3	92.28	22.08	49.92	20.28
5	3	3	106.02	29.38	64.32	12.32
5	1	4	92.84	21.58	61.36	9.90
5	2	4	94.83	23.29	59.94	11.60
5	3	4	71.91	29.48	34.27	8.16
6	1	1	109.78	40.32	23.45	46.01
6	2	1	87.94	36.45	15.00	36.49

Table B-2. Continued

TRT	REP	STAGE	TZN	ZNRO	ZNSH	ZNCO
6	3	1	78.61	32.85	16.52	29.24
6	1	2	114.79	43.20	46.24	25.35
6	2	2	70.11	19.47	21.84	28.80
6	3	2	57.27	23.20	18.49	15.58
6	1	3	124.96	30.15	84.73	10.08
6	2	3	136.07	38.76	87.74	9.57
6	3	3	90.76	33.60	50.40	6.76
6	1	4	105.14	25.60	73.78	5.76
6	2	4	120.97	26.55	88.92	5.50
6	3	4	112.28	36.00	70.30	5.98
7	1	1	114.11	32.56	26.55	54.99
7	2	1	104.19	36.49	22.62	45.08
7	3	1	88.48	36.48	25.60	26.40
7	1	2	84.04	22.55	34.84	26.65
7	2	2	85.72	31.39	26.04	28.29
7	3	2	61.42	20.52	25.30	15.60
7	1	3	125.84	35.52	66.80	23.52
7	2	3	105.95	31.59	51.48	22.88
7	3	3	92.24	24.96	50.00	17.28
7	1	4	82.95	19.09	53.94	9.92
7	2	4	92.54	18.26	58.28	16.00
7	3	4	80.51	28.71	43.40	8.40
8	1	1	81.59	30.21	15.50	35.88
8	2	1	66.06	13.20	12.54	40.32
8	3	1	73.94	28.80	22.94	22.20
8	1	2	105.41	55.44	22.23	27.74
8	2	2	56.28	21.08	9.20	26.00
8	3	2	67.74	32.00	20.16	15.58
8	1	3	106.91	41.61	48.98	16.32
8	2	3	103.23	48.48	44.55	10.20
8	3	3	79.51	40.80	30.55	8.16

Table B-2. Continued

TRT	REP	STAGE	TZN	ZNRO	ZNSH	ZNCO
8	1	4	121.99	45.57	64.26	12.16
8	2	4	104.51	45.54	49.61	9.36
8	3	4	84.86	39.60	37.26	8.00
9	1	1	81.58	31.85	8.32	41.41
9	2	1	101.07	48.64	7.28	45.15
9	3	1	68.36	35.64	6.72	26.00
9	1	2	72.44	21.66	25.96	24.82
9	2	2	84.36	27.39	24.57	32.40
9	3	2	91.81	38.54	35.99	17.28
9	1	3	60.77	35.28	12.69	12.80
9	2	3	142.92	48.10	83.60	11.22
9	3	3	99.90	34.06	58.00	7.84
9	1	4	131.50	24.40	98.60	8.50
9	2	4	129.51	31.99	92.48	5.04
9	3	4	170.12	66.88	95.12	8.12
10	1	1	83.39	35.28	20.91	27.20
10	2	1	69.14	21.42	15.08	32.64
10	3	1	53.37	17.40	16.50	19.47
10	1	2	113.28	58.46	30.68	24.14
10	2	2	80.63	32.80	20.88	26.95
10	3	2	56.81	22.77	15.68	18.36
10	1	3	121.06	50.47	58.59	12.00
10	2	3	98.52	42.12	43.50	12.90
10	3	3	38.20	16.40	15.60	6.20
10	1	4	82.52	40.00	31.36	11.16
10	2	4	97.38	38.48	49.29	9.61
10	3	4	43.94	21.62	16.74	5.58

Table B-3. Dry weights of seedlings and portions thereof for soybean plants treated with different nutrient solutions

TRT	REP	STAGE	TWT	ROWT	SHWT	COWT
1	1	1	2000	460	500	1040
1	2	1	2080	540	540	1000
1	3	1	2030	640	510	880
1	4	1	2190	610	410	1170
1	1	2	2700	1110	730	860
1	2	2	2480	1100	780	600
1	3	2	2500	1020	770	710
1	4	2	2290	960	530	800
1	1	3	3880	1530	1870	480
1	2	3	3770	1740	1610	420
1	3	3	3700	1050	2180	470
1	4	3	3400	1070	1800	530
1	1	4	5990	2210	3500	280
1	2	4	6210	2300	3690	220
1	3	4	6430	2160	3970	300
1	4	4	7390	2300	4700	390
2	1	1	2000	580	410	1010
2	2	1	2290	890	440	960
2	3	1	1970	630	430	910
2	4	1	2220	770	350	1100
2	1	2	2300	860	590	850
2	2	2	2490	1050	760	680
2	3	2	2200	900	510	790
2	4	2	2230	940	540	750
2	1	3	3600	1870	1260	470
2	2	3	3560	1770	1330	460
2	3	3	3180	1360	1330	490
2	4	3	3630	2050	1220	360
2	1	4	7820	4370	3250	200
2	2	4	6870	2870	3780	220
2	3	4	7560	3500	3860	200
2	4	4	6360	2870	3320	170
3	1	1	2020	600	420	1000
3	2	1	2180	780	410	990
3	3	1	2070	700	390	980
3	4	1	2150	650	510	990
3	1	2	2140	830	620	690
3	2	2	16300	8600	7000	700
3	3	2	2340	850	740	750
3	4	2	2530	1180	620	730
3	1	3	3630	1480	1660	490
3	2	3	2950	980	1570	400
3	3	3	2820	1150	1270	400
3	4	3	3430	1540	1420	470
3	1	4	7430	3740	3400	290
3	2	4	5440	2190	2890	360
3	3	4	6410	2310	3800	300
3	4	4	6790	2500	4000	290

Table B-3. Continued

TRT	REP	STAGE	TWT	ROWT	SHWT	COWT
7	1	1	1850	460	400	990
7	2	1	1730	340	290	1100
7	3	1	1800	300	440	1060
7	4	1	1980	660	390	930
7	1	2	2200	760	640	800
7	2	2	2330	800	560	970
7	3	2	2570	1220	420	930
7	4	2	2300	870	670	760
7	1	3	3260	1380	1340	540
7	2	3	2630	880	1250	500
7	3	3	2650	1020	1140	490
7	4	3	3100	1200	1300	600
7	1	4	4930	1650	2910	370
7	2	4	4800	1460	3050	290
7	3	4	4150	1820	2020	310
7	4	4	5740	2050	3430	260
8	1	1	2010	630	370	1010
8	2	1	2080	630	370	1080
8	3	1	2230	700	370	1160
8	4	1	2200	670	330	1200
8	1	2	2590	1280	520	790
8	2	2	2610	1270	600	740
8	3	2	2300	1130	530	640
8	4	2	2600	1430	500	670
8	1	3	3180	1780	660	740
8	2	3	3230	1750	980	500
8	3	3	2570	1410	710	450
8	4	3	3020	1680	740	600
8	1	4	4010	2080	1550	380
8	2	4	4680	2360	2000	320
8	3	4	5710	2830	2600	280
8	4	4	4800	2330	2170	300
9	1	1	2010	510	400	1100
9	2	1	2220	560	380	1280
9	3	1	2110	650	420	1040
9	4	1	2220	820	430	970
9	1	2	2170	730	600	840
9	2	2	2340	820	650	870
9	3	2	2790	1130	700	960
9	4	2	2650	1020	720	910
9	1	3	3530	1240	1740	550
9	2	3	3610	1430	1620	560
9	3	3	3170	1120	1630	420
9	4	3	2890	1070	1370	450
9	1	4	6800	2480	4120	200
9	2	4	6780	3260	3300	220
9	3	4	6470	2060	4270	140
9	4	4	6820	2710	3920	190

Table B-3. Continued

TRT	REP	STAGE	TWT	ROWT	SHWT	COWT
10	1	1	2380	840	420	1120
10	2	1	1990	540	360	1090
10	3	1	2230	810	360	1060
10	4	1	1930	620	300	1010
10	1	2	2260	1030	480	750
10	2	2	2290	1040	380	870
10	3	2	2400	1280	500	620
10	4	2	2340	1150	470	720
10	1	3	2590	1170	980	440
10	2	3	2750	1340	880	530
10	3	3	2780	1580	750	450
10	4	3	3030	1660	860	510
10	1	4	4110	1740	2060	310
10	2	4	5060	2640	2150	270
10	3	4	5200	2320	2680	200
10	4	4	5240	2410	2590	240
11	1	1	2070	700	360	1010
11	2	1	1890	600	310	980
11	3	1	2350	940	390	1020
11	4	1	2370	900	500	970
11	1	2	2420	1000	540	880
11	2	2	2630	1410	530	690
11	3	2	2580	1080	600	900
11	4	2	2520	1050	590	880
11	1	3	3470	1730	1260	480
11	2	3	3330	1680	1280	370
11	3	3	2960	1650	900	410
11	4	3	3430	1740	1190	500
11	1	4	5400	2630	2460	310
11	2	4	5940	2950	2730	260
11	3	4	6930	3270	3370	290
11	4	4	6260	2810	3210	240
12	1	1	2180	710	580	890
12	2	1	1830	600	400	830
12	3	1	2010	680	430	900
12	4	1	2230	770	470	990
12	1	2	2590	1280	560	750
12	2	2	2310	1010	640	660
12	3	2	2320	1060	460	800
12	4	2	2500	1110	570	820
12	1	3	3680	1620	1390	670
12	2	3	3830	1860	1520	450
12	3	3	3330	1680	1150	500
12	4	3	4020	2080	1480	460
12	1	4	7630	3430	3800	400
12	2	4	6950	2660	3990	300
12	3	4	7800	3260	4150	390
12	4	4	6850	2850	3740	260

Table B-3. Continued

TRT	REP	STAGE	TWT	ROWT	SHWT	COWT
4	1	1	2160	810	350	1000
4	2	1	1940	530	360	1050
4	3	1	2200	740	350	1110
4	4	1	1850	460	360	1030
4	1	2	2160	810	410	940
4	2	2	1970	730	380	860
4	3	2	2460	990	470	1000
4	4	2	2360	1060	400	900
4	1	3	2530	1210	760	560
4	2	3	2350	1000	830	520
4	3	3	3010	1410	1100	500
4	4	3	3080	1480	1160	440
4	1	4	3580	2040	1320	220
4	2	4	3230	1170	1800	260
4	3	4	3770	1330	2170	270
4	4	4	6450	3520	2740	190
5	1	1	13501	9400	4001	100
5	2	1	2010	760	350	900
5	3	1	2050	700	420	930
5	4	1	2220	810	360	1050
5	1	2	2660	1150	510	1000
5	2	2	2080	980	520	580
5	3	2	2170	920	590	660
5	4	2	2500	1050	610	840
5	1	3	3410	1590	1300	520
5	2	3	3520	1680	1360	480
5	3	3	2670	1040	1060	570
5	4	3	2690	1180	1010	500
5	1	4	5290	1550	3350	390
5	2	4	5590	1850	3450	290
5	3	4	6410	1910	4220	280
5	4	4	5610	1820	3420	370
6	1	1	2200	800	340	1060
6	2	1	2300	900	390	1010
6	3	1	2380	960	430	990
6	4	1	2370	820	500	1050
6	1	2	2660	1190	720	750
6	2	2	2740	1150	680	910
6	3	2	2980	1260	890	830
6	4	2	2650	1200	750	700
6	1	3	3770	1540	1700	530
6	2	3	3150	1230	1390	530
6	3	3	3440	1710	1360	370
6	4	3	3530	1440	1710	380
6	1	4	5530	2650	2660	220
6	2	4	6520	2800	3520	200
6	3	4	6720	2750	3790	180
6	4	4	7280	3220	3940	120

Table B-3. Continued

TRT	REP	STAGE	TWT	ROWT	SHWT	COWT
13	1	1	2330	690	440	1200
13	2	1	2320	750	460	1110
13	3	1	2320	770	500	1050
13	4	1	2340	760	410	1170
13	1	2	2280	900	670	710
13	2	2	2440	1000	700	740
13	3	2	2870	1450	750	670
13	4	2	2450	1120	600	730
13	1	3	3310	1400	1510	400
13	2	3	4110	1980	1660	470
13	3	3	4090	2080	1620	390
13	4	3	3650	1870	1260	520
13	1	4	5990	2320	3400	270
13	2	4	5200	2030	2890	280
13	3	4	6870	3050	3600	220
13	4	4	6810	2450	4160	200
14	1	1	1710	310	330	1070
14	2	1	1620	320	290	1010
14	3	1	1950	650	310	990
14	4	1	2010	640	340	1030
14	1	2	2130	770	390	970
14	2	2	1930	670	300	960
14	3	2	2510	1120	540	850
14	4	2	2280	900	560	820
14	1	3	2050	920	530	600
14	2	3	2270	960	660	650
14	3	3	2560	1120	940	500
14	4	3	2310	1150	610	550
14	1	4	4040	1440	2310	290
14	2	4	4370	1530	2640	200
14	3	4	4210	1600	2300	310
14	4	4	6042	1802	4000	240

Table B-4. Dry weights of seedlings and portions thereof for soybean seedlings treated with different nutrient solutions

TRT	REP	STAGE	TWT	ROWT	SHWT	COWT
1	1	1	3540	320	2400	820
1	2	1	3530	330	2300	900
1	1	2	8020	1000	6600	420
1	2	2	5370	770	4000	600
1	1	3	2980	1230	1460	290
1	2	3	2050	860	910	280
1	1	4	4680	1840	2650	190
1	2	4	4140	1610	2340	190
2	1	1	1580	530	310	740
2	2	1	8630	4700	3200	730
2	1	2	2020	1050	630	340
2	2	2	2550	1430	640	480
2	1	3	2870	1780	810	280
2	2	3	3550	2400	790	360
2	1	4	3300	1200	1950	150
2	2	4	3610	1430	1910	270
3	1	1	4630	540	3300	790
3	2	1	1630	280	260	1090
3	1	2	2170	1070	680	420
3	2	2	1940	980	510	450
3	1	3	3460	2290	900	270
3	2	3	3210	1590	1380	240
3	1	4	2200	940	1150	110
3	2	4	2790	1060	1630	100
4	1	1	1300	240	250	810
4	2	1	3540	230	2400	910
4	1	2	1580	610	570	400
4	2	2	1730	710	640	380
4	1	3	1880	800	690	390
4	2	3	1950	870	720	360
4	1	4	2100	880	900	320
4	2	4	2220	940	990	290
5	1	1	1320	400	290	630
5	2	1	1650	630	340	680
5	1	2	1720	730	620	370
5	2	2	2040	1030	630	380
5	1	3	2220	600	1270	350
5	2	3	2110	700	1040	370
5	1	4	2330	550	1600	180
5	2	4	2500	680	1700	120
6	1	1	1450	270	290	890
6	2	1	1490	300	280	910
6	1	2	1900	860	400	640
6	2	2	1840	710	330	800
6	1	3	2490	890	1370	230
6	2	3	2990	970	1670	350
6	1	4	3980	1300	2550	130
6	2	4	3050	1000	1880	170

Table B-4. Continued

TRT	REP	STAGE	TWT	ROWT	SHWT	COWT
7	1	1	1520	230	280	1010
7	2	1	1330	270	260	800
7	1	2	1440	520	540	380
7	2	2	1500	350	800	350
7	1	3	2500	920	1250	330
7	2	3	2000	660	1000	340
7	1	4	3150	720	2220	210
7	2	4	2950	1000	1820	130
10	1	1	1370	120	270	980
10	2	1	1300	130	270	900
10	1	2	1160	170	350	640
10	2	2	1160	170	390	600
10	1	3	660	140	210	310
10	2	3	750	150	300	300
10	1	4	340	110	110	120
10	2	4	430	110	220	100
11	1	1	1370	340	320	710
11	2	1	1280	280	300	700
11	1	2	1440	490	460	490
11	2	2	1400	510	430	460
11	1	3	1820	670	770	380
11	2	3	1870	760	700	410
11	1	4	2170	880	990	300
11	2	4	2100	860	940	300
12	1	1	1210	200	230	780
12	2	1	1360	350	300	710
12	1	2	1420	580	480	360
12	2	2	1640	640	540	460
12	1	3	1510	470	700	340
12	2	3	1830	540	910	380
12	1	4	2620	980	1470	170
12	2	4	2220	810	1230	180
13	1	1	1370	300	230	840
13	2	1	1480	270	290	920
13	1	2	1580	630	490	460
13	2	2	1710	660	620	430
13	1	3	1760	670	770	320
13	2	3	2200	1030	790	380
13	1	4	1880	790	940	150
13	2	4	2370	1040	1160	170
14	1	1	1450	390	330	730
14	2	1	1460	330	270	860
14	1	2	1550	480	350	720
14	2	2	1760	460	700	600
14	1	3	1370	520	560	290
14	2	3	1630	580	710	340
14	1	4	1710	900	630	180
14	2	4	2120	890	940	290